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Cincinnati, Ohio

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EMERGENCY REUSE OF WATER AT CHANUTE, KANSAS, 1956-57

by

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ABSTRACT

From October, 1956 to March, 1957 the City of Chanute, Kansas, (population 12,000) faced with a critical water shortage, resorted to use of its sewage as a source of water supply. This paper reports on the treatment methods used, some of the problems which arose, and the water quality studies which were made during the period of water recirculation. No adverse effects on the health of the people were noted but much of the population used other sources of drinking water because of the various objectionable characteristics of the public supply.

Details of illustrations in this document may be better studied on microfiche.

INTRODUCTION

The increasing use of water and the attendant problems of providing additional supply have given rise to much speculation and discussion regarding the possible future use of sewage treatment plant effluents and other waste waters as supplemental sources of public water supply. A number of industries presently treat and re-cycle waste waters or use municipal sewage to conserve water or to reduce stream pollution, or both. Few cities, if any, have practiced re-cycling of their own sewage for use in public water supply systems, although a great many do draw water from rivers containing large quantities of sewage discharged by upstream cities.

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Heavily polluted waters have been successfully purified in properly designed modern water treatment plants.(1) To some few persons who are perhaps overly imbued with a sense of local pride, this seems to pose the question of "whose sewage is best". This is definitely a minority viewpoint, however, and the great majority of water consumers take a dim view of deriving all or any small part of their drinking water from the local sewage treatment plant effluent, regardless of the purification processes employed or the quality of the finished product. This feeling arises principally from esthetic considerations but is also supported by questions regarding the safety of the water from a health standpoint. Thus, cities are understandably reluctant to propose re-cycling of waste waters even under severe emergency water supply conditions, and in some communities it would not be considered under any circumstances. As a result, there is little or no information available on the operation of water plants utilizing waste waters and the problems involved have not been studied heretofore under field conditions.

WATER SHORTAGE AT CHANUTE

During the recent drought of 1952-1957, the most severe in Kansas history, the city of Chanute was intermittently plagued by water shortages. Normally this town of 12,000 persons obtains its supply from the Neosho River, using an average of about 1.4 mgd and a maximum of about 2 mgd. Local industries account for a substantial part of this water use. A program of water conservation reduced water consumption about 25 percent and extended the time during which the available supply could be used.

However, the situation became progressively worse, and in the summer of 1956 the Neosho River ceased to flow. Chanute used portable equipment to pump water from upstream pools over riffles to the city's channel storage reservoir above the water works dam. This operation extended upstream about 10 miles to a pool just below the Humboldt city sewage plant outfall. Figure 1 is a map of southeastern Kansas showing the cities using the Neosho River as the source of their water supply. The drainage area above Chanute is about 4,000 square miles.

As the drought continued it became evident that additional action was necessary to supply water to the city. The city officials investigated and considered several possibilities:

1. Discontinue water service to large industrial water users and conserve the available supply for domestic use.

This idea was rejected because it was a very temporary solution at best and meant the loss of livelihood for many Chanute residents as well as substantial direct financial losses by the industries. The principal industries were a cement plant, an oil refinery and a wax plant.

2. Develop a well water supply.

This alternative was extensively studied prior to and during the drought. In the immediate vicinity of Chanute the yield of wells is meager and the water is highly mineralized. The best source of well water was found to lie in an aquifer of limited area about 4 miles west of the city. Water from this source was not considered suitable as a permanent supply because of its total

hardness of 725 mg/l and its sulfate content of 630 mg/l. Development of this source would involve the drilling and equipping of 7 wells to a depth of 150 feet, construction of about 5 miles of pipe line, and the purchase of the necessary rights-of-way for wells and pipe lines. The high cost and temporary nature of this project together with the time required for its completion caused it to be rejected.

3. Haul potable water by truck or rail.

The nearest suitable sources were Kansas City and Pittsburg. (See Figure 1). Even at the reduced freight rates which were offered, the cost of hauling was estimated at $4 per 1000 gallons. The number of tank cars required and the logistics of loading, transporting, and unloading also posed some serious problems. The cost and physical limitations of this method caused it to be judged impracticable.

4. Join with other cities along the Neosho River to pump water from the Smoky Hill River to the upper end of the Neosho.

Some preliminary investigations had been made of a proposal to install two pump stations and about 18 miles of pipe line for temporary service in pumping water from the Smoky Hill River near Junction City over the divide (static head = 400 feet) and into the upper end of the Neosho River. From this point it would flow by gravity to serve the 13 cities utilizing the Neosho as a source of water supply. This is illustrated in Figure 1. Not shown are the Cedar Bluff and Kanopolis Reservoirs, water from which could be released, if necessary, to supplement the flow of the Smoky Hill

River to provide for this diversion. At the time of the water shortage in Chanute, Emporia was the only other city interested in this proposition. Even with all 13 cities (combined population 59,000) participating, the expense of operating such a project would have been high because of the large initial cost and water losses in transit due to seepage and evaporation from the river. If the drought had continued through 1957, this proposal undoubtedly would have received more serious consideration.

5. Recirculate treated sewage.

This final proposal is the one which the city officials elected to follow. The city had completed a new secondary sewage treatment plant in 1953. They were justifiably proud of this plant and its efficient operation. The concentration of coliform organisms in the sewage treatment plant effluent was considerably lower than that normally found in Neosho River water at the city's water intake. Much of the river flow past Chanute during the drought was made up of sewage plant effluent from upstream communities and the city had been using this water for several months without any known ill effects. The relative locations and elevations of the reservoir behind the water works dam and the outfall sewer were such that the waste water could easily be diverted under controlled conditions to channel storage without pumping. The only construction required was a small earth dam across the river channel below the sewer outfall. Furthermore, this plan could be placed into effect almost immediately.

The decision to recirculate treated sewage was made entirely by the city officials. In describing the various means of providing emergency water supply, the authors have attempted to present them as they were viewed by the city officials at the time without implying either concurrence or criticism.

RECIRCULATION OF TREATED SEWAGE

On October 14, 1956, without fanfare, the city opened the valve which permitted mixing of treated sewage with water stored in the river channel behind the water works dam. Figure 2 is a schematic diagram of the re-cycling process which was thus established.

DESCRIPTION OF WATER SUPPLY SYSTEM

The city of Chanute obtains its water supply from a Neosho River impoundment formed by a low overflow dam located about one mile downstream from the water works intake. At spillway level the storage pool is about 200 feet wide and 2 miles long and contains about 60 million gallons.

Under normal operating conditions, raw water is pumped to a plain sedimentation basin of 1.9 mg capacity. The settled water is treated with alum, lime, soda-ash, and chlorine in a solids contact softening unit of 70,000 gallons capacity. The water then flows to a final settling basin of 0.9 mg capacity. The influent to this basin is recarbonated by a natural-gas fired underwater burner. Chlorine is added just before and just after rapid sand filtration. There are six filters each rated at 1/2 mgd at 2 gals/sq.ft./minute. The filters are backwashed by either of 2 pumps each having a capacity of 2,600 gpm (15 gal/sq.ft./minute). The

finished water is stored in two underground reservoirs having a combined capacity of 247,000 gallons, and pumped into the distribution system serving the city. An elevated steel tank provides 250,000 gallons storage on the distribution system.

DESCRIPTION OF SEWAGE TREATMENT PLANT

The sewage treatment plant was completed in 1953. Normally the treatment processes consist of a bar screen, wet well and pump station, grit chamber, primary clarifier of 160,000 gallons capacity, two trickling filters loaded at about 800 lbs. of BOD/acre ft./day, final clarifier holding 160,000 gallons, a separate heated sludge digester, and sludge drying beds. Treated sewage can be recirculated from the bottom of the final tank to the wet well where it is mixed with the incoming raw sewage. This is practiced normally only during the low flow period at night.

The outfall sewer from the sewage treatment plant discharges into the Neosho River at a point about 300 feet downstream from the water works dam.

TEMPORARY ARRANGEMENTS FOR THE EMERGENCY REUSE OF WATER

By constructing a temporary earth dam across the river channel about 200 feet downstream from the sewer outfall, a body of treated sewage was formed about 200 feet wide by 500 feet long. The surface elevation of this pool was slightly higher than the water level behind the water works dam. Existing valves in the dam were available to regulate the flow of water back through the dam into the water works intake pool.

When the valve was opened to begin the re-cycling process, on October 14, 1956, there were approximately 15 million gallons of water in storage in the intake pool. This in effect added a waste stabilization pond of about 17 days average retention to the treatment process. City water use during the period of recirculation averaged about 1 1/4 mgd. Restrictions on the use of water for non-conserved air-conditioning had been in effect since 1955, and the use of water for car washing and lawn sprinkling had been prohibited for a period of several months. The average daily flow at the sewage treatment plant during the recirculation period was 3/4 mg. The total theoretical time for a complete water cycle through the water softening plant, the sewage treatment plant, and the stabilization pond in the river channel was about 20 days.

From the beginning of recirculation on October 14, 1956 until December 20, 1956 only two changes were made in the treatment processes. At the water plant 1/2 to 3/4 grain per gallon of alum was added ahead of the the presedimentation basin. At the sewage plant continuous recirculation was practiced within the plant by returning 600 gpm from the bottom of the final clarifier to the wet well in order to secure a higher degree of treatment. During this period the total chlorine dosage at the water plant was 6 to 7 mg/l. The chlorine was fed ahead of the solids contact basin and just before and/or just after filtration.

On December 14, 1956, through newspaper stories, the fact that re-use of water was being practiced at Chanute came to the attention of the Kansas State Board of Health for the first time. The city officials were contacted and it was agreed that additional precautions should be taken.

These included the chlorination of the sewage treatment plant effluent, the pre-chlorination of raw water at the softening plant, and the more frequent collection of raw water and tap water samples for bacteriological examination.

On December 21, 1956 chlorination equipment was placed in operation at the sewage treatment plant. At the start, a dose of 25 mg/l was applied to the plant effluent. After one week, the chlorine applied was reduced to 10 mg/l, and operation was continued at this level until recirculation was stopped on March 14, 1957.

On December 20, 1956 the first point of chlorination at the water plant was changed from the effluent to the influent of the pre-sedimentation basin to take advantage of the lower pH and longer contact period provided, and the chlorine dosage was increased. From December 20, 1956 to January 10, 1957 about 10 to 15 mg/l of chlorine was applied to the raw water, and an additional 1 to 1.5 mg/l was added in the clear well. On January 11, 1957 the pre-chlorination dose was reduced to 6 to 7 mg/l with the same rate of post-chlorination; this was continued for the duration of re-cycling.

Bacteriological sampling was increased from a weekly to a daily schedule. At least one sample of raw water and one sample of tap water was collected each day.

OPERATING EXPERIENCE

SEWAGE TREATMENT PLANT

Aside from the additional operating chores which were involved in chlorinating the plant effluent and continuously recirculating within the

plant to secure more complete treatment, there were no appreciable effects on operation of the sewage treatment plant. There was an unprecedented awareness on the part of local residents and their neighbors in nearby communities of the fact that Chanute did own and operate a sewage treatment plant. Spectators from near and far visited the plant to observe its operation. The recirculation process gave rise to a whole new line of jokes, most of which will not bear repeating here. The plant operators bore up remarkably well under the barrage of humor aimed in their direction.

During the period of water reuse the sewage treatment plant removed, on the average, 86 percent of the biochemical oxygen demand (BOD) and 76 percent of the chemical oxygen demand (COD). It provided substantial reduction in both total and ammonia nitrogen concentrations. Sewage treatment also reduced alkyl benzene sulfonate (A.B.S.) an average of 25 percent and complex phosphates by 67 percent.

STABILIZATION POND

The impounding reservoir served very effectively as a waste stabilization pond. It reduced the applied BOD and COD loadings, by approximately 75 percent; the total and ammonia nitrogen concentrations by more than 55 percent; and the A.B.S. by over 50 percent.

WATER TREATMENT PLANT

Operating difficulties at the water plant were perhaps less serious than might have been expected under the circumstances. The high ammonia content of the raw water made break-point chlorination impractical for taste and odor control and complete color removal. Figure 3 shows the

chlorine demand curve of a raw water sample with a good break-point at a chlorine dosage of 130 mg/l. The break occurred at the expected figure of about ten times the ammonia concentration..

Froth was a nuisance in the operation of the plant, and on occasion provided a spectacular display for passersby on the highway adjacent to the water plant. Most of the froth was produced by agitation of water in the recarbonation basin. On still days the froth would accumulate to a depth of 10 to 15 feet, completely covering and hiding the small building which housed the CO_2 compressor. Figure 4 is a view of this structure. On windy days, large clouds of froth would be wafted into the air and carried downwind. This frothing was due principally to the high concentration of synthetic detergents in the recirculated water.

Coagulation and settling were less effective than under normal circumstances. There was considerable carryover of floc particles onto the filters. There was no evidence of rising floc such as occurred at Osawatomie, Kansas [2] when detergent concentrations were high.

The most serious trouble occurred in operation of the rapid sand filters. This can be attributed partly to the character of the applied water, but defects in the filters aggravated the situation. The capacity of the wash water sewer was barely sufficient to carry away the flow usually required for backwashing. The influent valves leaked and allowed settled water to enter the filters at a rapid rate during backwashing. This made it necessary to reduce the rate of backwash to avoid exceeding the wash water sewer capacity.

Deposits were observed on the sand grains and the size of the grains

increased rapidly. About three months after recirculation started, it was necessary to clean the filter sand manually. Each filter was taken out of service, the sand removed and cleaned by agitation in a concrete mixer while applying liberal quantities of water. At the same time the filter influent valves were removed and repaired. After the sand was replaced in the filters, each unit was backwashed from 15 to 20 times. Considerable frothing occurred and additional quantities of foreign material were removed from the beds. No detailed analyses were made of the coating on the sand grains but, because of its solubility in hydrochloric acid, it was believed to be largely calcium carbonate. The frothing which occurred during backwashing suggested that synthetic detergent materials or other surface active substances were also present. The sand had a strong fishy odor similar to that of decomposing algae or other organic material.

Determinations at the plant laboratory gave false evidence of free chlorine residuals by the orthotolidene-arsenite (O.T.A.) procedure. The "flash" colorimetric method also gave erroneous readings of 2.0 mg/l of free residual chlorine in the presence of 1.6 to 12.0 mg/l of ammonia nitrogen in the tap water. The amperometric titration procedure showed no evidence of the presence of free chlorine. The total combined chlorine residual as measured by amperometric titration averaged about 5.0 mg/l at the plant tap during the period of water reuse. The use of the color comparator was discontinued and all chlorine residual measurements were made amperometrically. To supplement frequent laboratory tests, a continuous chlorine residual recorder was installed on a plant tap.

The treated water had several objectionable characteristics. It had a pale yellow color and an unpleasant musty taste and odor. The tap water was high in chlorides, total solids, and organic content which added to the taste and odor problem. Agitation of the water, as in drawing a glass of it from the tap, caused frothing because of the high A.B.S. content. (See Figure 5). The frothing of the tap water served as a constant unpleasant reminder of the source of the city's water supply. A "head" on a glass of beer is fine, but a similar "head" on a glass of water is less attractive. The cooling tower at the municipal power plant caused considerable comment due to the constant "snow storm" of froth produced by it. Because of the location of the power plant near the downtown business district, the clouds of froth sailing above the streets caused pedestrians and vehicles alike to dodge skillfully to avoid a direct hit by a ball of suds.

The water was unsuitable for most laboratory purposes. Even after double distillation it could not be used for making standard solutions or mixing reagents because of carryover.

WATER QUALITY STUDIES

Following preliminary discussions by telephone and letter, a conference was held at Lawrence, Kansas on January 3, 1957 by Kansas State Board of Health and U. S. Public Health Service representatives to plan an intensive study of the reuse of water at Chanute.

Arrangements were made for the collection and shipment of samples beginning January 15, 1957, and for various analyses to be performed at the Water and Sewage Laboratory in Lawrence and at the Sanitary Engineering

Center in Cincinnati. Four regular points were selected for collection of grab samples, namely (1) raw water, (2) treated water, (3) raw sewage, and (4) treated sewage prior to chlorination. Additional Sampling points would be utilized as indicated by developments during the course of the work. It was agreed that reasonably representative samples of sewage plant effluent could be obtained at 10 to 11 AM, which time was also convenient for immediate shipment of samples.

In general, the Water and Sewage Laboratory was to make the physical and chemical analyses, and the bacteriological examinations by standard dilution techniques and the immediate membrane filter method. The Sanitary Engineering Center was to make special chemical tests and examine samples for zoological organisms, viruses, and plankton, as well as for coliform organisms by the delayed membrane filter procedure where applicable Standard Methods procedures were used.(3)

Information on the collection, preservation and transportation of samples is given in Table 1. All samples were collected by the District Sanitarian or other State Department of Health personnel.

CHEMICAL QUALITY

Chlorides

The relationships between rainfall, stream flow, water level fluctuations in the intake pool during the period of reuse of water and chloride concentrations are given in Figure 6. The actual period of recirculation extended from October 14, 1956 to March 14, 1957. Information over a longer time is shown to include the transition periods at the start and

finish and to furnish a basis for comparison with normal conditions.

There was no measurable flow in the Neosho River from August 29, 1956 through February 15, 1957. The gage readings show the effects of pumping water over riffles from pools upstream in late September, October, and early November, 1956. From early November, 1956 until the middle of February, 1957 the amount of water in storage in the water works intake pool remained fairly constant at 20 to 25 million gallons. The only losses were from evaporation, seepage, and consumptive water use. On February 15, 1957 light rains occurred on the watershed above Chanute which brought in some fresh water, although the water level remained below the spillway and recirculation was continued until March 14. Further rains on March 21 put water over the spillway. Heavy general precipitation on March 31 produced an additional rise of 8 feet and ended the five year drought.

With cessation of stream flow in August, there was an almost immediate increase in chloride content from the normal of about 40 mg/l. By the time recirculation was started in October the chlorides nad increased to about 180 mg/l. The build-up continued steadily to values of 400 to 500 mg/l during January and February. Light rains provided sufficient dilution to reduce the concentration to about 400 mg/l during March. Following the heavy spring rains the chlorides dropped abruptly to normal concentrations.

Domestic and other municipal uses of water result in increased concentrations of chlorides. Studies reported by the State Water Pollution Control Board of California (4) indicate this increase in chlorides from tap water to sewage to be about 20 to 50 mg/l. Table 2 shows chloride data

obtained in the Chanute study. Results of 15 analyses of tap water and raw sewage show an apparent average increment of 32 mg/l. This apparent increase may be higher than the true value; however, the test results show an average chloride concentration in the raw and treated sewages of 511 and 485 mg/l respectively. There is no reason to believe that chlorides were removed in sewage treatment. This indicated reduction in chlorides probably resulted from use of grab samples which did not represent the same sewage before and after treatment.

The chloride increase during the recirculation period indicates that the water was reused about 10 times. Other methods of estimating the number of cycles give values between 8 and 15.

Interpretation of the chloride data is complicated by the unknown quantities of highly mineralized oil field brines which entered the river in the vicinity of the water works for at least a part of the time that recirculation was practiced.

Ponds and transmission ditches used for water flooding oil formations in the immediate area permitted seepage of the brine downward to a thin alluvium which was intersected by the river channel. Faulty maintenance of these facilities caused some accidents which contributed significant amounts of brine to the supply.

Chemical Indicators of Pollution

Analytical data which indicate the build-up of pollution in the raw water are nitrogen in its various forms, chemical and biochemical oxygen demands, alkyl benzene sulfonate, and total and ortho phosphates.

The detailed laboratory results are presented in Tables 3, 4, and 5. The pollution load resulting from re-cycling of water was already substantial at the time of the first sampling on January 15. Thereafter, as illustrated by Figures 7 and 8, the concentrations of total and ammonia nitrogens, BOD, and A.B.S. continued to increase until February rains provided some dilution. At the peak, the raw water contained 17 mg/l of nitrogen, 5.8 mg/l of A.B.S., and had a BOD of 13 mg/l.

Table 6 shows the efficiency of sewage treatment and the overall treatment process in reducing the concentration of the selected pollution indicators during the period of maximum concentrations of these substances. The complex phosphates were the most completely removed, 97 percent, while the A.B.S. was the most persistent with only 68 percent removed.

The remarkable effectiveness of the raw water impoundment in reducing concentrations of these various substances is apparent. It is particularly striking in the case of total nitrogen and ammonia. There is no clear evidence as to the mechanism by which the ammonia was removed, but it is clear that the two to three weeks storage in this shallow impoundment resulted in major improvement in water quality. It is doubtful if recirculation could have continued as long as it did except for this storage.

The average increase in A.B.S. concentration from treated water to raw sewage was 10.4 mg/l and the average increase in phosphate concentration was 40.4 mg/l of which 18.2 mg/l was orthophosphate and the remainder complex phosphates. A major part of the phosphate increment is due to synthetic detergents. Prior to the use of these detergents, sewage nor-

mally contained about 5 mg/l of phosphorus as PO_4. Phosphates were effectively removed in the water treatment plant, undoubtedly in the softening process. The water treatment plant was not very effective in removing A.B.S., COD or various forms of nitrogen.

Figure 7 is a graphical presentation of the total and ammonia nitrogen, BOD and COD in treated sewage, raw water, and tap water. Figure 8 shows the variations during the period of study in A.B.S. and total phosphates in treated sewage and raw and tap waters.

In determining the concentration of A.B.S. in water samples three different analytical procedures were used. The Water and Sewage Laboratory at Lawrence used the methylene blue method. At Cincinnati the methyl green[5] and extraction-infrared[6] procedures were followed. Table 7 shows the good agreement between the values obtained by the three methods.

Alkalinity, pH, and Hardness

Table 8 shows the variations in pH, alkalinity and hardness of raw and treated sewage and raw and tap waters during the study. Some of these data are plotted on Figure 9. The hardness of the treated water increased to rather a high level during the period of recirculation. Normally the water is softened to about 100 mg/l.

A comparison of the effectiveness of lime and soda-ash in reducing hardness during the recirculating period with periods of normal operation shows that at the doses used both of these softening chemicals were fully effective. The plant operators reported that increased doses of softening chemicals only resulted in the carryover of more floc particles to the filters.

Total Solids and Sulfates

The data for sulfates, total solids, and specific conductance are given in Table 9. The relationships between sulfates and the total solids present in treated sewage, raw water, and tap water are shown in Figure 10.

Studies reported by the California Water Pollution Control Board (4) showed that domestic and other municipal uses of water increase the sulfate concentration by 15 to 30 mg/l. During the period of no flow in the Neosho River at Chanute, the increase in sulfate concentration from treated water to treated sewage was 26 mg/l. Although the treated sewage had an average sulfate content of 111 mg/l, that of the raw water was only 79 mg/l. This reduction indicates some anaerobic decomposition in the raw water impoundment.

The total solids content of Chanute tap water usually is in the range of 200 to 500 mg/l. Recirculation resulted in an increase to 1000 to 1200 mg/l, although a part of this increase can be attributed to oil field brines reaching the water in the intake pool.

Carbon Filter Tests

Carbon filters were operated for sampling the tap water at Chanute during two periods. Unfortunately both of the periods were after the February 15 rains had brought about some improvement in water quality, so no data are available on the content of extractable organic material in the water during the period of heaviest contamination. This technique has been described previously in the Journal. (7)(8)

Table 10 shows the results on the two samples along with typical results from three other waters for purposes of comparison. The Columbia River at Bonneville Dam is relatively free of pollution and the total extractable organic load is only 120 µg/l. At Wyandotte, Michigan, the Detroit River is affected by much of the industrial and other wastes from the Detroit area and in spite of the large flow the extractable organics amount to 465 µg/l of which somewhat less than half is in the chloroform extract. The Merrimack River at Lawrence, Massachusetts, is affected by considerable municipal and industrial waste and shows 743 µg/l of extractable organics with about the same proportion of chloroform and alcohol extract as at Wyandotte.

As a rule it has been found that the chloroform extractable fraction contains the most highly odorous materials and is more characteristic of industrial waste pollution than the alcohol extract.

The two Chanute samples show that although the extractable organic load was quite high it was not inordinately higher than at Lawrence, Massachusetts and about five-sixths of this was in the alcohol extract. During the period when these two samples were collected, the concentration of A.B.S., COD and ammonia were from one-half to two-thirds as high as during the period immediately before the rains of February 15. The concentration of extractable organics in these samples was probably below the peak concentration by about this same factor.

The alcohol extract from the first of the Chanute samples was assayed for detergent using extraction and infrared methods for identification. The A.B.S. content was 28 percent. Although this procedure does not

recover surfactants quantitatively, this indicates that a major fraction of the total extractable organics was A.B.S.

Threshold odor determinations during the period Jan. 22 to March 19 showed predominently a musty odor in both the raw and treated water. The maximum threshold odor number in the treated water was 16 and, as a rule, the treated water had a higher threshold odor number than the raw water.

Miscellaneous Chemical Analyses

As noted previously under the description of the water softening plant, the water at Chanute is fluoridated to 1.0 ppm. Normally the raw water contains about 0.3 ppm of fluoride. During the recirculation period, the fluorides in the intake pond increased to about 0.8 ppm. The desired concentration in the tap water was maintained by decreasing the quantity of fluoride compound added in water treatment.

Table 11 gives typical complete chemical analyses of tap water before, during, and after the re-cycling of water. The increase in sodium concentration from a normal value of from 30 to 60 mg/l to about 380 mg/l is notable. This has some significance for persons with cardiac ailments requiring a restricted sodium diet.

BIOLOGICAL QUALITY

Coliform Organisms

The number of coliform organisms in the raw water during the period of recirculation was considerably less than that found in Neosho River water at Chanute under normal conditions. This is shown by Figure 11 which gives

the most probable number (MPN.) of coliform bacteria per 100 ml in the Chanute raw water from May, 1956 through July, 1957. The portion of the curve from October 14 to December 21, 1956 reflects the efficiency of sewage treatment and the stabilization pond. The portion of the curve from December 21, 1956 to March 14, 1957 shows the increased efficiency resulting from chlorination of the sewage treatment plant effluent. The highest raw water MPN for the period during which the sewage effluent was being chlorinated was 330, and the average was near 20. For the periods shown before and after recirculation the MPN exceeded 9000 per 100 ml at times, and averaged about 1,500.

After chlorination of raw water was started at the water plant on December 20, 1956, the water in the first basin had an MPN of less than 3.0/100 ml as shown by examination of 14 samples tabulated in Table 12.

From October 14, 1956 to March 14, 1957 (the re-cycling period) 560 ten milliliter portions (112 samples) of tap water were examined in accordance with Standard Methods in the Water and Sewage Laboratory at Lawrence. Only one tube or 0.23 percent of the 10 ml portions examined was positive. This sample was collected on November 24, 1956 before chlorination of the sewage treatment plant effluent and prechlorination of raw water were started.

In addition, 11 special samples each of raw and treated water were collected from the Chanute water treatment plant during February and March, 1957. These samples were iced and transported to the laboratory at Lawrence for planting the same day. They were examined for coliform bacteria by both the immediate MF (membrane filter) and MPN dilution

procedures. Portions of each sample were also filtered through two membrane filters, placed on inhibiting medium and sent to the Sanitary Engineering Center for incubation and examination.

The MF examinations of the raw water were made by filtering 10 ml to 50 ml portions of each sample through each of two membranes. The MPN dilution examination involved 5 portions each of 10, 1, 0.1 and 0.01 ml, confirmed test. Treated water data were based on 100 to 200 ml portions filtered through each of two MF, and that for MPN procedure on 10 plantings of 10 ml portions, confirmed test. The results are shown in Table 13.

Coliform bacteria were detected in the treated water on three separate days, twice by the immediate MF procedure and once by the delayed MF method. In no case were coliform bacteria detected by more than one procedure in any one treated water sample. The maximum density reported was only 1 per 100 ml.

Thus, the tap water, as judged by standard tests, was of satisfactory bacteriological quality during the entire time that water was being reused.

Plankton

Samples for examination of plankton were preserved with formalin and examined without concentration in a Sedgwick-Rafter counting cell under 100 X magnification. Figure 12 and Table 14 show results of the counts.

Algae forms were abundant in the stabilization pond in spite of the relatively low temperature. The average water temperature during

January and February was 42°F. A small green alga Ankistrodesmus was the dominant form. This alga has a volume of about 80 cubic microns.

During the first half of February, algae counts were as high as 40,000 organisms per ml in the raw water. The water treatment plant removed less than 80 percent of the algae during the early part of the study. After the filters were reworked the removal efficiency increased but generally the overall removal was less than 90 percent. Table 14 also shows that the treatment prior to filtration was generally not very effective in removing algae.

Zoological Organisms

One gallon samples of sewage effluent and raw water were concentrated in a Scharples centrifuge; 1 gallon samples of finished water were concentrated by filtering through SS type membrane filters. In addition, 5 gallon concentrates from finished water were prepared at the treatment plant. A general survey type of examination under low magnification was made of every concentrate collected for worms and other large zoological organisms. When the concentrates of finished water samples contained algae and dead particulate matter in quantities which did not interfere with protozoa examination, these organisms were counted and roughly identified.

Concentrates of each sample were inoculated into tubes of modified Cleveland endamoeba medium (9) for detection of E. histolytica and other parasitic protozoa that grow in this medium. A few drops of each concentrate from finished water samples were planted on buffered sucrose nitrate agar for detection of live cysts of free-living (non-pathogenic) amoebae.

A favorable bacterial flora was used in the former, and Pr. mirabilis was used in the latter detection.

Positive cultures for parasitic protozoa were subjected to iron-haematoxylin staining for identification of species.

The results obtained in both cultural and direct microscopic examinations of these samples are summarized in Table 15. The following highlights may be observed.

On one occasion (6th sample) E. histolytica was detected in the sewage effluent. On two occasions (4th and 5th samples) Trichomonas sp. were detected in the sewage effluent, in one of which (5th sample) this parasite was accompanied by another intestinal flagellate, Chilomastix mesnili. On one occasion (5th sample), the raw water was found to have the parasitic flagellate, Trichomonas sp.. The occurrence of these parasitic protozoa in only three of ten samples of sewage effluent indicates that these organisms were relatively scarce in Chanute sewage during the study.

In nine of the ten samples of finished water live cysts of free living (non-pathogenic) amoebae were detected. The presence of these cysts as well as significant numbers of algae in the finished water shows the relatively low efficiency of the water treatment plant in removing particulate matter in the 5-20 micron size range. Figure 13 is a photomicrograph of the concentrate from a finished water sample collected February 4, 1957. The arrows point to two amoebic cysts. Most of the organisms shown are the small algae Ankistrodesmus. The larger round black objects are Euglena. The field shown in this photograph includes material from approximately 15 ml of water.

In the third and eighth samples a few live larvae of Anguillula-like nematode worms were found in the finished water. These worms were identified as Monhystera sp. and were given the species name, M.aquatius. Most of the worms found in the raw water were dead but a few live ones were almost always present. These worms are relatively resistant to chlorine and evidently the chlorine doses used were insufficient to kill all of them.

Virus

During the past several years there has been an increasing interest on the part of public health workers in the potential role of sewage and sewage-contaminated water in the transmission of human enteric viruses. This interest intensified in 1955 when an outbreak of infectious hepatitis occurred in New Delhi, India.(10) This epidemic resulted in an estimated 20,000-40,000 cases, and was apparently spread by the treated water of the city. Certain laboratory studies(11)(12) demonstrate that the problem of removing viruses from water poses questions as to the adequacy of present methods of treatment, and the New Delhi epidemic gives reason for additional concern with the problem.

The enteric viruses which are most likely to produce readily recognized diseases are well-known - infectious hepatitis, poliomyelitis and perhaps Coxsackie and the adenoviruses. Still other viruses causing less severe diseases conceivably can be spread by a water supply and not be recognized by available epidemiological techniques. Non-specific diarrheas or "grippe" probably rank next to the common cold as sources of discomfort and economic loss in man-hours. Yet these diseases are usually not severe

enough to require treatment by a physician - and even more important - they are presently non-reportable diseases. Thus, the epidemiologist has no statistics available for assessing the morbidity, and the microbiologist is just beginning to acquire data and techniques for studying the causative agents of these diseases.

In the past five years more and more viral agents have been isolated from human feces; not only from cases of recognized disease but from a good proportion of the healthy population. A useful grouping of the enteric viruses is as follows:

1. Infectious hepatitis
2. Poliomyelitis - 3 types
3. Coxsackie - More than 20 types have been described
4. Adenovirus - 18 types $\pm$ to date. Responsible for upper-respiratory and ocular disease found not only in throat secretions, but in feces and sewage.
5. ECHO or Orphan viruses - Enteric cytopathogenic agents of human origin. Usually have been isolated from apparently normal individuals while screening for incidence of polio virus. Some of these agents have been associated with aseptic meningitis and diarrhea in children, but many have not been associated with any clinical disease. More than 20 types have been identified.

With this broad and simple classification scheme we now have a total of greater than 60 virus agents, all pathogenic, which may be excreted in the feces of man.

At least one type of each of these five major groups of viruses has been isolated from urban sewage, with the exception of infectious hepatitis virus. Failure to demonstrate this latter agent in sewage is undoubtedly only a reflection of the lack of a laboratory method of recognizing it.

Materials and Methods: Samples were collected, preserved and shipped as shown in Table 1. A 500 ml portion of raw sewage samples was homogenized in a Waring Blendor for 2 minutes. The homogenate was then centrifuged at 10,000 rpm for 30 minutes in a Servall SS1 centrifuge. The top one-half of the supernate from this centrifugation was carefully removed and re-centrifuged in the same manner. The top one-half of the supernate from this centrifugation was removed and 2000 units of penicillin, 2.0 mg of dihydrostreptomycin, and 0.25 mg of aureomycin were added to each ml of supernate. After standing one hour at room temperature, each of 25 monkey kidney tissue culture tubes was inoculated with 0.1 ml of the material, and each of 25 additional tubes was inoculated with 1.0 ml of the material. The tubes were placed in a roller drum for 1 to 2 hours, removed, the medium completely drawn off and replaced with fresh medium. The tubes were then replaced in the roller drum for the duration of the experiment.

Treated sewage, raw water and tap water samples were treated by alum flocculation (13) to concentrate virus. A sample volume of 2,900 ml was used. The settled floc was packed by low speed centrifugation and the supernate removed. The floc was then mixed with 1.4 percent sodium carbonate and held for 1 hour with intermittent agitation in order to elute the virus. The floc was again centrifuged at low speed and 10 ml

of the supernate added to 90 ml of monkey kidney tissue culture medium. Two ml of this medium were then added to each of 50 monkey kidney tissue culture tubes and the tubes placed in a roller drum for 24 hours. The tubes were then removed, the medium completely withdrawn and replaced with fresh medium. The tubes were then replaced in the roller drum for the duration of the experiment.

Virus Detection Systems: Rhesus monkey kidney tissue cultures, about 6 days old, were used to detect those enteric viruses known to produce cytopathogenic effects in them. These tissue culture tubes are susceptible to all three types of poliomyelitis virus, to the ECHO viruses, to at least some of the Adenoviruses, and to most of the Coxsackie B viruses. The majority of the samples were also inoculated into suckling mice to detect the presence of Coxsackie A viruses.

Results

Table 16 summarizes the results of virus examination of all samples. Two definitely positive isolations were made, from treated sewage collected on January 22 and January 29, 1957. These two isolations produced a typically characteristic polio or Coxsackie-like cytopathogenic effect in monkey kidney tissue cultures. The table also shows 6 other samples as yielding questionable results. The cytopathogenic effects observed in these tubes are unlike anything seen in this laboratory before, and it is believed that they may be viruses present in the monkey kidney tissue cultures themselves and did not come from the inoculated material. Final identification of all of these viruses should help to clarify their original source.

Discussion

Although only two of the forty samples examined have yielded definitely positive results for viruses, it is of interest to calculate the amount of virus present in the original sample.

The sewage treatment plant effluent collected on January 22, 1957 resulted in 4 positive tubes in the total of 50 inoculated. Preliminary tests indicate that these four tubes included viruses of the ECHO, Coxsackie and poliomyelitis groups. In this sample, the virus content of the whole 2,900 ml original volume was concentrated to about 10 ml and all of this material was inoculated into the tissue culture tubes. If the efficiency of the concentration procedure were 100 percent, only 4 infectious doses were present in the original material, assuming that only one infectious dose of virus was inoculated into each tube. However, in experiments not yet completed, the concentration procedure used in this study has been shown to be only 10 to 30 percent effective in recovering virus. If we assume a 20 percent efficiency of the procedure, and not 100 percent, the 4 infectious doses actually represent an original concentration of 20 infectious doses.

The sewage treatment plant effluent collected on January 29, 1957 resulted in only 1 positive tube in the total of 50 inoculated. This has been identified as a poliomyelitis virus. Using the assumptions described above, the original 2,900 ml of treated sewage contained 5 infectious doses of virus.

These results are in general agreement with the data reported by Kelly (14) on her recent survey of enteric viruses in sewage. Her studies were made from June, 1954 through May, 1955. She reported a total of about 135 positive enteric virus isolations from raw and treated sewage. Only 4 of these were made during the months of January, February and March. By far the greatest number of positive isolations were made during the "poliomyelitis season", July through October.

None of the treated water samples examined showed the presence of virus.

HEALTH EFFECTS

There were no known cases of water-borne disease or other adverse effects upon health resulting from the use of the recirculated water. The evidence supporting this conclusion is only presumptive, however, since no systematic morbidity studies were carried out. Because of the sensitive public relations and public opinion problems involved, it was decided that a backward rather than a forward look would be preferable in studying morbidity.

On January 29, 1958 representatives of the State Board of Health met with the local medical society. The results of the special study were reported to the physicians and their comments solicited. They were specifically questioned about their clinical observations during the period of water reuse. The general conclusion was that no illness could be traced to the reclaimed water supply. They reported that stomach and intestinal disturbances were much more prevalent and widespread in the fall

and winter of 1957-58 than during the same period the previous year when water reuse was practiced. The physicians were, of course, fully aware of the possibilities and alert for any indication of trouble. Patients were also cognizant of the situation and there was a general tendency to blame almost any kind of sickness on the water, particularly stomach or intestinal upsets. One interesting report was to the effect that one physician's patients had complained of dermatitis from bathing in the water.

The clinical observations by local physicians and the laboratory data are in agreement as to the safety of the water. The tap water met the Drinking Water Standards (15) for bacteriological quality during the entire period, and the special biological tests did not reveal the presence of pathogenic organisms. In evaluating the laboratory evidence, however, it is well to keep in mind the limitations of the techniques available at present, the difficulties involved in the isolation of specific disease-producing organisms, and the possible limitations of the coliform test under the prevailing conditions.

The chemical quality of the water became progressively worse during re-cycling. Again, no harmful effects were reported. The total solids content of 1,000 to 1,200 mg/l might have produced laxative effects on persons from outside the community not accustomed to use of highly mineralized water. Local residents were apparently not affected probably due to the slow build-up in total solids which occurred over a period of several weeks.

The high sodium content (about 380 mg/l) of the water was potentially significant for patients under restricted sodium therapy. For the great majority of persons in normal health, the additional sodium was no problem since properly functioning body organs adjust output rapidly and precisely to conform with intake. However, some persons with one of several very common diseases of the heart, kidney, and liver are unable to rid themselves of sodium. Depending upon the severity of the disorder, special diets are prescribed limiting sodium intake from 250 milligrams to 2.5 grams. Since water is one of the major dietary sources of sodium, such patients are usually advised to use distilled water for drinking and culinary purposes. For this reason it is doubtful that the high sodium content produced any actual effects even on these few patients.

CONSUMER ACCEPTANCE

Initial public acceptance of the water was good, probably because the citizens knew their supply normally received diluted treated sewage from seven upstream communities. No public mention of the move was made until after recirculation had been started. Public reaction became more adverse when stories appeared in the local papers. Bottled water sales boomed and virtually all grocery stores carried a large stock. Exact figures on the total quantity of bottled water sold are not available, but one of the two major distributors reported the sale of 40,000 gallons. Water was sold in 5 gallon containers at a cost of 20 cents per gallon plus $1.50 for the bottle which was not refunded.

More than 70 private wells were drilled, but most of the water pumped from them was too highly mineralized for domestic purposes and was

used primarily for car washing, lawn watering, and other purposes for which use of city water was prohibited. Water was hauled from neighboring towns and farm wells by some people. The city and the Santa Fe Railroad hauled a total of 150,000 gallons of water into the city and made it available at a central location free to the public for drinking purposes. One cement plant which could not use high chloride water hauled 20 million gallons of water over a 9 day period at a total cost of $100,000.

PLANS FOR PREVENTION OF RECURRENCE

City officials are anxious to prevent a recurrence of the water shortage. They have initiated studies of possible sites for storing water on tributaries, but to date have not proceeded with detailed planning. The John Redmond and Council Grove reservoirs have been authorized by the Congress for flood control. Planning is under way and construction funds are being requested by the Corps of Engineers for July, 1958. Both of these upstream reservoirs on the Neosho River will have conservation pools for maintaining minimum flows. Because their construction will make a reservoir for the city unnecessary, Chanute officials are supporting the Corps' construction budget before Congress.

SUMMARY

In 1956-57, during the most severe drought in Kansas history, the city of Chanute, on a temporary emergency basis, recirculated treated sewage through a stabilization pond, the water treatment plant, and the water distribution system. One complete cycle required about 20 days time.

The re-cycling process was employed for a period of 5 months in the fall and winter of 1956-57. During the first two months, the only special

treatment provided was recirculation within the sewage treatment plant to obtain a better effluent. Further safeguards added during the last three months of operation included chlorination of the sewage plant effluent, pre-chlorination of raw water, the installation of a continuous chlorine residual recorder, and more frequent bacteriological testing.

There were no special problems in the operation of the sewage treatment plant. The water works impounding reservoir served very effectively as a waste stabilization pond. In the 17 days retention provided by this intake pool, substantial reductions were obtained in BOD, COD, total and ammonia nitrogens and detergents.

Difficulties at the water treatment plant included:

a. The inability to practice breakpoint chlorination for taste and odor control and color removal due to the extremely high chlorine demand of the raw water.

b. Frothing at the recarbonation basin and in the rapid sand filters during backwashing was a nuisance to operators.

c. Coagulation and settling were less effective than under normal circumstances.

d. Plugging and coating of the filter sand occurred.

e. False high readings of free chlorine residuals were obtained by the orthotolidine-arsenite test.

The treated water had a pale yellow color and an unpleasant musty taste and odor. It foamed when agitated and contained undesirable quantities of dissolved minerals and organic substances.

When the quality was at its worst, the raw water contained 17 mg/l of nitrogen, 5.8 mg/l of A.B.S. and had a BOD of 13. Chloride concentrations

increased from normal values of about 40 mg/l to a peak of 670 mg/l. The average increment per cycle was about 32 mg/l. Sulfates increased, on the average, about 26 mg/l from treated water to treated sewage. The total solids content of tap water increased from a normal of 200 to 500 mg/l to 1,000 to 1,200 mg/l.

Carbon filter sampling of tap water during periods not representative of the most severe conditions showed average extractables in parts per billion of: chloroform 159, alcohol 685, and total 844.

The number of coliform organisms in the raw water during the period of recirculation was less than that found when the Neosho River is flowing at Chanute. The tap water met the Drinking Water Standards for bacteriological quality throughout the period of reuse.

Algae in the raw water varied from 2,000 to 45,000 per ml. The predominant organism was the very minute green alga, Ankistrodesmus which was poorly removed by water treatment.

The concentration of E. histolytica and other parasitic protozoa in Chanute's sewage was low during this period and these organisms were not found in the treated water. However, cysts of free living amoebae comparable in size to E. histolytica were found regularly in the treated water indicating relatively low treatment plant efficiency in removing such organisms.

Two positive isolations of virus were made from treated sewage samples. These samples contained viruses of the poliomyelitis, ECHO and Coxsackie groups. No virus was detected in the treated water. There were no known adverse effects on health from use of the recirculated water.

Consumer acceptance of the water was poor, and many persons obtained their drinking water from other sources. One industry, a cement plant which

could not use high chloride water spent $100,000 in hauling 20 million gallons of water during a 9 day period.

CONCLUSIONS

The reuse of sewage to supplement deficient water supplies should not be considered or permitted except under the most severe emergency conditions. It is certainly a last resort, after all other possible sources of supply have been fully investigated.

With the degree of treatment provided at Chanute, it is doubtful that the process could have been continued for more than a few weeks beyond the 5 month period.

The most serious problem is that of public acceptance, or more accurately, public rejection of the water; although there are also serious technical difficulties to be overcome. People are willing to pay many times the normal cost to get a safe and palatable water.

The accumulation of nitrogen makes breakpoint chlorination impractical and renders tests and odor control and color removal difficult.

The studies demonstrate the effectiveness of chlorine as a disinfectant, even under very adverse conditions. Bacteriological quality as judged by the coliform test was excellent.

A rapid increase occurs in the concentration of dissolved salts and organic material, many of which are not amenable to removal by ordinary processes. More information is needed on how effective more elaborate treatment may be in removing some of these pollutants.

There are many unresolved questions concerning the safety of re-cycled water from a public health standpoint, despite the apparently favorable results obtained in the Chanute study. Standard laboratory

techniques available to water plant laboratories are not adequate to detect the presence of some pathogens which may be present in heavily polluted waters and the health significance of some of the organic chemical contaminants which may be present is not known.

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Emergency Reuse of Water
Chanute, Kansas, 1956-1957.

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TABLE 1

COLLECTION, PRESERVATION AND TRANSPORTATION OF SAMPLES
DURING EMERGENCY REUSE OF WATER, CHANUTE, KANSAS, 1957.

Analysis or Examination	Sample Location*	Sample Volume (ml)	Container	Types and Amounts of Preservatives Added	Transportation Refrigeration	Transportation Carrier	Time (hrs.)
Samples for State Department of Health Laboratory, Lawrence, Kansas							
Chemical and Physical	1	4000	Polyethylene, p.s.c.	None	Iced	Bus	4
	2	4000	"	"	"	"	
	3	4000	"	"	"	"	
	4	4000	"	"	"	"	
Coliform Bacteria	1	500	Glass, g.s.	0.05 g. $Na_2S_2O_3 \cdot 5H_2O$	Iced	Bus	4
	1a	500	"	0.05 g. "	"	"	
	2	500	"	0.05 g. "	"	"	
Samples for Robert A. Taft Sanitary Engineering Center, Cincinnati, Ohio							
Virus	1	4000	Glass, r.s.	0.4 g. $Na_2S_2O_3 \cdot 5H_2O$ + 5×10^5 units penicillin + 1g. dihydrostreptomycin[x]	Iced	Bus & Air Express	24[xx]
	2	4000	"	0.4 " " + 5×10^5 " " + 1g. "	"	"	
	3	500	"	0.05 g. " " + 6.2×10^4 " " + 125 mg "	"	"	
	4	4000	"	0.4 g " " + 5×10^5 " " + 1g. "	"	"	
Zoological Organisms	1	4000**	Glass, r.s.	0.5 g $Na_2S_2O_3 \cdot 5H_2O$	Iced	Bus & Air Express	24[xx]
	2	4000**	"	0.5 g " "	"	"	
	4	4000	"	0.5 g " "	"	"	
Plankton	1	2000	Polyethylene, p.s.c.	50 ml commercial formalin	None	R.R. Express	168 ±
	1a	2000	"	50 ml " "	"	"	
	2	2000	"	50 ml " "	"	"	
	4	2000	"	50 ml " "	"	"	
Spectrographic and Cation	1	4000	Polyethylene, p.s.c.	None	Iced	Bus & Air Express	24[xx]
	2	4000	"	"	"	"	
Coliform Bacteria	1	-	Ointment Tins	M. F. on inhibiting medium in ointment tin.	-	Air Mail	48 ±
	2	-	" "	"	-	" "	

* Sample 1 - Raw water; 1a - Settled water; 2 - Tap water; 3 - Raw sewage; and 4 = Treated, but unchlorinated sewage

** Starting March 5, additional samples were collected by filtering 5 gallons through several Type SS 0.047 mm MF which were then placed in 50 ml distilled water.

x Penicillin and dihydrostreptomycin solution was freshly prepared, and added to samples immediately following their collection.

xx Samples taken January 22 and February 4 were delayed an additional 24 hours.

TABLE 2

CHLORIDE CONCENTRATIONS DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957
(mg/l Cl)

Date 1957	Raw Water	Tap Water	Increment, Tap Water to Raw Sewage	Raw Sewage	Treated Sewage
Jan. 15	510	510	+20	530	530
" 22	460	500	+20	520	520
" 28	530	520	+20	540	540
" 30	530	540	+30	570	560
Feb. 4	510	520	+30	550	510
" 6	500	500	0	520	460
" 11	480	470	+50	520	470
" 13	500	500	+20	520	500
	Rain, Neosho River Flows Again				
" 19	570	520	+20	540	520
" 20	670	550	+10	560	530
" 26	400	480	+40	520	510
Mar. 5	380	400	+70	470	450
" 12	390	390	+50	440	430
" 19	360	390	+80	470	400
" 26	360	380	+10	390	340
Average	477	479	+32	511	485

TABLE 3

TOTAL, AMMONIA, NITRITE AND NITRATE NITROGEN CONCENTRATIONS DURING EMERGENCY REUSE OF WATER, CHANUTE, KANSAS, 1956-1957
(mg/l N)

Date 1957	Total N				Ammonia N				Nitrite N				Nitrate N			
	Water		Sewage		Water		Sewage		Water		Sewage		Water		Sewage	
	R	T	R	T	R	T	R	T	R	T	R	T	R	T	R	T
Jan. 15	-	-	-	-	8.4	7.3	35	31	0.09	0.05	0.29	0.17	0.6	0.6	0.4	1.7
" 22	10.0	11.0	70	33	8.4	9.7	46	26	0.08	0.05	0.15	0.24	0.7	0.8	0.3	1.6
" 28	14.0	12.0	64	34	12.0	10.0	42	27	0.12	0.06	0.26	0.20	0.9	1.0	0.5	1.6
" 30	13.0	12.0	56	33	11.0	10.0	40	27	0.11	0.05	0.14	0.15	0.4	0.4	0.4	1.0
Feb. 4	16.0	14.0	82	33	13.0	12.0	53	28	0.11	0.06	0.17	0.17	0.4	0.5	0.6	1.2
" 6	16.0	14.0	74	33	14.0	11.0	46	26	0.09	0.03	0.17	0.17	0.4	0.8	0.5	0.5
" 11	17.0	16.0	96	37	13.0	12.0	57	30	0.10	0.05	0.28	0.22	0.2	0.3	0.4	0.4
" 13	17.0	15.0	95	38	13.0	10.0	57	36	0.10	0.05	0.24	0.22	0.5	0.2	0.3	1.0
	Rain, Neosho River Flows Again															
" 19	7.8	14.0	95	39	4.8	12.0	52	32	0.05	0.03	0.22	0.21	0.1	0.4	0.6	0.8
" 20	1.3	11.7	92	33	0.3	9.5	57	25	0.01	0.04	0.30	0.19	<0.01	0.2	0.5	0.6
" 26	4.6	1.9	77	27	3.4	1.6	47	20	0.04	0.02	0.07	0.19	0.1	0.04	0.2	0.3
Mar. 5	6.0	5.4	78	31	3.4	4.7	46	24	0.08	0.04	0.11	0.19	0.1	0.2	0.1	0.3
" 12	5.3	4.9	84	33	3.8	3.8	49	23	0.06	0.02	0.07	0.27	0.1	0.2	0.2	0.9
" 19	4.8	3.6	73	23	3.0	2.7	44	17	0.08	0.02	0.00	0.36	0.3	0.2	0.6	2.5
" 26	3.5	2.8	61	22	2.5	2.0	34	16	0.07	0.02	0.13	0.33	0.3	0.3	0.8	2.8

TABLE 4

ALKYL BENZENE SULFONATE AND PHOSPHATE CONCENTRATIONS
DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957

Date 1957	Alkyl Benzene Sulfonate (mg/l ABS)				Phosphate (mg/l PO_4)							
					Ortho				Total			
	Water		Sewage		Water		Sewage		Water		Sewage	
	R	T	R	T	R	T	R	T	R	T	R	T
Jan. 15	3.6	3.5	15.0	9.1	11.4	2.6	27.5	24.5	13.4	3.2	41.5	32.0
" 22	3.5	4.2	12.0	11.0	10.4	3.4	22.0	31.0	11.4	3.6	34.5	36.5
" 28	4.1	4.0	11.0	10.0	11.8	3.6	19.5	17.0	13.4	4.1	35.0	25.0
" 30	4.1	4.1	11.0	10.0	10.0	3.8	22.0	21.5	12.0	4.2	30.0	30.0
Feb. 4	5.3	5.1	16.0	10.0	11.6	3.0	19.0	15.0	13.0	3.7	42.0	22.5
" 6	5.8	4.6	13.0	10.0	11.8	3.3	17.0	15.5	13.4	3.8	32.5	22.5
" 11	5.1	4.8	17.0	10.0	12.8	3.0	25.5	23.5	14.6	3.4	66.0	28.0
" 13	5.7	5.1	14.0	13.0	13.6	4.6	25.5	28.5	15.0	5.0	46.0	34.5
Rain, Neosho River Flows Again												
" 19	2.3	4.7	13.0	11.0	5.4	2.4	16.5	26.0	6.8	2.6	35.0	30.5
" 20	0.4	3.9	12.0	10.0	0.4	2.1	23.5	19.5	0.8	2.3	43.0	25.0
" 26	1.6	0.9	8.3	7.8	3.1	0.4	18.5	23.5	3.5	0.5	31.5	27.0
Mar. 5	1.8	1.9	13.0	8.8	4.5	1.2	22.0	29.5	4.6	1.1	51.5	32.5
" 12	1.8	1.7	17.0	9.1	4.1	2.8	18.5	24.5	4.5	2.9	59.0	28.5
" 19	1.6	1.5	16.0	8.3	3.3	0.6	18.5	24.5	3.4	0.6	52.0	26.5
" 26	1.4	1.4	18.0	7.2	2.5	0.7	13.0	17.0	2.7	0.7	49.0	20.0

TABLE 5

CHEMICAL AND BIOCHEMICAL OXYGEN DEMANDS
DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957

Date 1957	B O D (mg/l) Water R	Water T	Sewage R	Sewage T	C O D (mg/l) Water R	Water T	Sewage R	Sewage T
Jan. 15	4.6	-	180	47	44	36	540	160
" 22	5.1	-	220	31	45	42	570	180
" 28	4.7	-	190	31	58	44	570	160
" 30	5.3	-	130	32	54	41	440	160
Feb. 4	7.2	-	240	24	59	45	700	130
" 6	7.2	-	200	18	58	42	610	160
" 11	11.0	-	275	22	63	44	1080	140
" 13	13.0	-	235	28	71	52	740	160
	Rain, Neosho River Flows Again							
" 19	9.5	-	260	30	28	46	780	150
" 20	6.2	-	240	28	28	43	730	150
" 26	6.8	-	220	27	32	16	730	130
Mar. 5	7.8	-	250	35	36	24	800	140
" 12	6.5	-	320	35	36	28	950	140
" 19	5.8	-	280	19	35	24	850	120
" 26	-	-	-	-	32	20	860	120

TABLE 6

AVERAGE RESULTS OF SELECTED POLLUTION INDICATORS FOR PERIOD JANUARY 15 - FEBRUARY 13, 1957, CHANUTE, KANSAS

Pollution Indicator	Raw Sewage mg/l	Treated Sewage mg/l	Reduction in Sewage Treatment %	Raw Water mg/l	Treated Water mg/l	Overall Reduction Raw Sewage to Treated Water %
Nitrogen, total	78	34	56	15	13	83
Nitrogen, NH_3	47	29	38	12	10	79
C.O.D.	656	156	76	56	43	93
B.O.D.	209	29	86	7.3	-	-
A.B.S.	13.6	10.4	25	4.6	4.4	68
Phosphate, ortho	22	22	0	12	3.4	88
Phosphate, total	41	29	29	13	3.9	95
Phosphate, complex	19	7	67	1	0.5	97

TABLE 7

COMPARISON OF THREE ANALYTICAL PROCEDURES FOR DETERMINING THE ABS CONCENTRATION OF WATER, CHANUTE, KANSAS.

Date of Sampling 1957	Source	Analytical Procedure: Methylene Blue	Methyl Green	Extraction and infrared*
Jan. 22	Raw water	3.5	3.6	
" 22	Tap water	4.2	4.4	
Feb. 21	Tap water	4.7	4.9	3.5*
Mar. 5	Tap water	1.9	1.9	
" 12	Tap water	1.7	1.5	

*The extraction-infrared procedure is currently under investigation. The results are considered as unequivocal in that the sample has at least the concentration of ABS measured.

TABLE 8

ALKALINITY, pH, AND HARDNESS DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957

Date 1957	pH				Alkalinity								Hardness	
					Total				Phenolphthalein					
	Water		Sewage		Water		Sewage		Water		Sewage		Water	
	R	T	R	T	R	T	R	T	R	T	R	T	R	T
					mg/l $CaCO_3$				mg/l $CaCO_3$				mg/l $CaCO_3$	
Jan. 15	8.2	9.4	8.5	7.8	220	140	330	260	0	40	18	0	280	150
" 22	8.0	9.2	8.3	7.4	210	180	390	280	0	45	34	0	270	170
" 28	7.7	8.8	8.0	7.5	240	170	320	260	0	38	0	0	280	180
" 30	7.9	8.9	8.3	7.8	230	190	340	280	0	34	8	0	300	210
Feb. 4	8.0	8.9	8.3	7.7	240	180	380	260	0	27	0	0	270	180
" 6	7.9	8.6	8.4	7.6	240	170	380	260	0	20	16	0	260	180
" 11	8.1	8.8	8.3	7.6	240	190	440	280	0	30	Tr	0	240	180
" 13	8.1	8.4	8.1	7.7	240	210	420	310	0	20	0	0	250	220
					Rain, Neosho River Flows Again									
Feb. 19	8.2	9.0	8.7	7.7	210	160	430	290	0	30	42	0	390	190
" 20	8.2	9.0	8.1	7.9	190	140	380	250	0	28	0	0	500	220
" 26	8.1	8.7	8.1	7.6	180	120	340	230	0	14	0	0	310	240
Mar. 5	8.4	8.9	8.1	7.7	180	150	370	260	5	21	0	0	310	230
" 12	8.4	8.4	7.9	7.7	180	190	400	290	7.0	7.0	-	-	320	340
" 19	8.4	8.7	7.9	7.6	170	130	340	200	6.0	15	0	0	310	190
" 26	8.2	8.9	8.2	7.8	160	110	330	210	0	20	0	0	300	240

TABLE 9

SPECIFIC CONDUCTANCE, TOTAL SOLIDS AND SULFATES
DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957

Date 1957	Specific Conductance				Solids, Total				Sulfates			
	Water		Sewage		Water		Sewage		Water		Sewage	
	R	T	R	T	R	T	R	T	R	T	R	T
	Micromhos/cm				mg/l				mg/l		SO_4	
Jan. 15	2120	1990	-	2380	1180	1080	-	1290	77	78	-	100
" 22	2120	1990	-	2380	1090	1100	-	1330	72	83	-	110
" 28	2280	2100	-	2410	1230	1140	-	1300	85	85	-	105
" 30	2350	2250	-	2660	1240	1180	-	1360	84	85	-	105
Feb. 4	2140	2010	-	2230	1200	1150	-	1230	79	90	-	105
" 6	2260	2250	-	2320	1190	1140	-	1220	80	89	-	119
" 11	2060	1930	-	2240	1140	1070	-	1230	77	86	-	123
" 13	2360	2210	-	2660	1190	1120	-	1300	79	84	-	121
					Rain, Neosho River Flows Again							
" 19	2310	2130	-	2550	1330	1140	-	1350	60	89	-	141
" 20	2630	2240	-	2580	1460	1160	-	1320	44	81	-	118
" 26	1680	1810	-	2220	980	1030	-	1260	62	64	-	108
Mar. 5	1770	1770	-	2300	980	950	-	1200	71	78	-	116
" 12	1750	1780	-	2240	1000	1010	-	1220	79	83	-	121
" 19	1730	1700	-	2050	980	920	-	1090	76	85	-	120
" 26	1520	1460	-	1730	940	880	-	1050	70	80	-	150

TABLE 10

A COMPARISON OF THE ORGANIC CHEMICALS RECOVERED BY THE CARBON FILTER TECHNIC FROM CHANUTE TAP WATER WITH THOSE RECOVERED FROM CLEAN, MODERATELY POLLUTED AND HEAVY POLLUTED RIVER WATERS

City or River	Sampling Point	Sampling Period 1957	Volume Filtered gal.	Organics Recovered: Chloroform Extract ppb	Alcohol Extract ppb	Total Extract ppb
Chanute, Kansas	Tap	2/19-3/3	6048	214	778	992
" "	"	3/4-3/22	6530	121	600	721
Columbia River	Raw	at Bonneville Dam		33	87	120
Detroit River	"	at Wyandotte, Mich.		201	264	465
Merrimack River	"	at Lawrence, Mass.		322	421	743

Data on the river waters are from Middleton, F. M., Rosen, A. A., and Burttschell, Taste and Odor Research Tools for Water Utilities, Journal AWWA, 50: 21 (1958).

TABLE 11

COMPARISON OF TYPICAL CHEMICAL ANALYSES OF TAP WATER BEFORE, DURING, AND AFTER RECIRCULATION OF SEWAGE TREATMENT PLANT EFFLUENT CHANUTE, KANSAS

Chemical Analysis	Units	Before (4-12-56)	During (2-6-57)	After (7-13-57)
Calcium	mg/l	25.	44.	30.
Magnesium	"	11.	17.	8.0
Sodium	"	59.	379.	30.
Silica	"	3.0	6.5	10.
Iron	"	0.20	0.19	0.06
Manganese	"	0.00	0.00	0.00
Hardness, total	mg/l $CaCO_3$	108.	180.	108.
Hardness, carbonate	"	39.	174.	76.
Hardness, non-carbonate	"	69.	6.	32.
Alkalinity, total	"	39.	174.	76.
Alkalinity, $NaHCO_3$	"	0.	0.	0.
Carbonate	mg/l	3.6	24.	3.6
Bicarbonate	"	40.	163.	85.
Sulfate	"	101.	89.	49.
Chloride	"	63.	520.	23.
Nitrate	"	1.9	2.7	6.2
Fluoride	"	0.4	1.1	0.9
Total Solids	"	305.	1,139.	208.
Turbidity	units	5.	1.	Under 1.
pH	-	8.4	8.6	8.4

TABLE 12

COLIFORM BACTERIA IN THE WATER PLANT
PRE-CHLORINATED AND SETTLED WATER
CHANUTE, KANSAS 1956-1957

Date	Coliform Bacteria M.P.N./100 ml.
12-23-56	Less than 3.0
12-24-56	" " 3.0
12-25-56	" " 2.1
12-26-56	" " 2.1
12-27-56	" " 2.1
12-28-56	" " 2.1
12-29-56	" " 2.1
12-30-56	" " 2.1
12-31-56	" " 3.0
1-1-57	" " 3.0
1-2-57	" " 2.1
2-16-57	" " 3.0
3-6-57	" " 3.0
3-8-57	" " 3.0

TABLE 13

RESULTS OF THREE PROCEDURES USED IN DETERMINING COLIFORM DENSITIES IN RAW AND TAP WATERS DURING EMERGENCY REUSE OF WATER CHANUTE, KANSAS 1956-1957

Date 1957	Raw Water Coliform Bacteria per 100 ml			Tap Water Coliform Bacteria per 100 ml		
	Immediate MF Procedure	Delayed MF Procedure	MPN Dilution Procedure	Immediate MF Procedure	Delayed MF Procedure	MPN Dilution Procedure
Feb. 4	10	10	4	- 0.5	0.5	- 1.0
" 6	26	14	17	- 0.5	- 0.5	- 1.0
" 11	26	64	33	- 0.5	- 0.5	- 1.0
" 13	45	120	49	0.5	- 0.5	- 1.0
	Rain, Neosho River Flows Again					
" 19	57	150	330	1.0	- 0.5	- 1.0
" 20	85	180	33	- 0.5	- 0.5	- 1.0
" 26	75	60	49	- 0.25	- 0.25	- 1.0
Mar. 5	15	30	49	- 0.33	- 0.33	- 1.0
" 12	15	65	-	- 0.33	- 0.33	-
" 19	40	65	49	- 0.25	- 0.25	- 1.0
" 26	75	140	49	- 0.25	- 0.25	- 1.0

TABLE 14

PLANKTON ANALYSIS OF RAW, SETTLED AND FILTERED WATERS
DURING EMERGENCY REUSE OF WATER
CHANUTE, KANSAS 1956-1957

Date 1957	Raw Water	Influent to Filter		Filtered Water		Treated Sewage
	Count/ml	Count/ml	% of Raw Water Count	Count/ml	% of Raw Water Count	Count/ml
			TOTAL ALGAE			
Jan. 22	2400	-	-	520	22	1600
" 29	9300	-	-	2600	28	1900
Feb. 4	46000	-	-	7100	15	1200
" 13	45000	-	-	7100	16	880
			Rain, Neosho River Flows Again			
Feb. 18	17000	-	-	2200	12	1300
" 26	33000	-	-	200	1	530
Mar. 5	19000	2800	15	610	3	400
" 12	18000	7900	44	2100	12	1400
" 19	2900	580	20	160	6	90
" 26	2000	170	8	50	2	90
			ANKISTRODESMUS			
Jan. 22	1300	-	-	360	28	1100
" 29	8200	-	-	1900	23	110
Feb. 4	37000	-	-	3900	11	580
" 13	40000	-	-	6200	16	880
			Rain, Neosho River Flows Again			
Feb. 18	13000	-	-	2000	15	1100
" 26	32000	-	-	60	0.2	400
Mar. 5	17000	2700	16	560	3	180
" 12	14000	7400	53	2000	14	880
" 19	440	130	30	80	18	0
" 26	180	60	33	30	17	40

TABLE 15

RESULTS OF CULTURAL AND DIRECT MICROSCOPIC EXAMINATIONS
OF TREATED SEWAGE AND RAW AND TAP WATERS, CHANUTE, KANSAS 1957.

Date	1/22	1/28	2/4	2/12	2/20*	2/27	3/5**	3/12	3/19	3/26
Sample					CULTURAL FINDINGS					
					Endamoeba Histolytica					
Tap Water	-	-	-	-	-	-	-	-	-	-
Raw Water	-	-	-	-	-	-	-	-	-	-
Treated Sewage	-	-	-	-	-	+	-	-	-	-
					Trichomonas					
Tap Water	-	-	-	-	-	-	-	-	-	-
Raw Water		-	-	-	+	-	-	-	-	-
Treated Sewage	-	-	-	+	+	-	-	-	-	-
					Chilomastix					
Tap Water	-	-	-	-	-	-	-	-	-	-
Raw Water		-	-	-	-	-	-	-	-	-
Treated Sewage	-	-	-	-	+	-	-	-	-	-
					Free-Living Amoeba					
Tap Water	+	+	+	+	+	+	-	+	+	+
					DIRECT MICROSCOPIC FINDINGS					
					Free-Living Amoebic Cysts					
Tap Water	600/gal	300/gal	?	?	?	?	-	++	?	?
Raw Water	+++	+++	+++	+++	+++	++	++	+++	+++	+++
Treated Sewage	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
					Free-Living Ciliates					
Tap Water	-	-	?	?	?	?	-	-	?	?
Raw Water	+++	+++	+++	+++	+++	-	++	+++	+++	+++
Treated Sewage	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
					Free-Living Nonpigmented Flagellates					
Tap Water	-	-	?	?	?	?	-	++	?	?
Raw Water	++	++	++	++	++	+++	++	++	++	++
Treated Sewage	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++
					Free-Living Worms					
Tap Water	-	-	2	-	-	-	-	2	-	-
Raw Water	++d	++	++	++	++	++d	++d	++d	++d	++d
Treated Sewage	+++	+++	+++	+++	+++	+++	+++	+++	+++	+++

- \- Negative
- \+ Positive or Present
- ++ Few
- +++ Numerous
- ? No Count, Too many Algae
- d Dead

*Rain on February 15, Neosho River Flows Again.

**Volume of Tap Water Examined was 1 Gallon from 1/22 to 2/27 and 6 Gallons from 3/5 to 3/26.

TABLE 16

VIRUS ISOLATION FROM CHANUTE, KANSAS, JANUARY 22, THROUGH MARCH 26, 1957

Sample	Sample Collection Date									
	1-22-57	1-29-57	2-4-57	2-11-57	2-19-57	2-26-57	3-5-57	3-12-57	3-19-57	3-26-57
Raw Sewage	-	-	?	?	-	-	-	-	-	-
Sewage Plant Effluent	+	+	-	?	-	-	?	-	-	-
Water Treatment Plant Influent	-	-	?	-	-	-	?	-	-	-
Treated Water	-	-	-	-	-	-	-	-	-	-

+ = Cytopathogenic agent

- = No change

? = Experiments not yet completed

LIST OF FIGURES

Emergency Reuse of Water
Chanute, Kansas, 1956-1957

Figure No.	Title
1	Neosho River and Vicinity
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3	Breakpoint Chlorination Curve, Chanute, Kansas, 1957.
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5	Suds in Tap Waters from Chanute and Parsons, Kansas, 1957.
6	Water Level in Water Works Intake Pool and Chlorides in Tap Water During Emergency Reuse of Water, Chanute, Kansas, 1956-1957.
7	Nitrogen and Oxygen Demand Concentrations in Treated Sewage and Raw and Tap Waters, Chanute, Kansas, 1957.
8	Phosphate and A.B.S. Concentrations in Treated Sewage and Raw and Tap Waters, Chanute, Kansas, 1957.
9	Hardness and Alkalinity Concentrations in Sewage and Water Samples, Chanute, Kansas, 1957.
10	Total Solids and Sulfate Concentrations in Treated Sewage and Raw and Tap Waters, Chanute, Kansas, 1957.
11	Coliform Bacterial Densities in Raw Water During Emergency Reuse of Water, Chanute, Kansas, 1956-1957.
12	Plankton Counts in Raw, Settled and Tap Waters During Emergency Reuse of Water, Chanute, Kansas, 1957.
13	Photo-micrograph of Organisms in Concentrated Tap Water, Chanute, Kansas, 1957.

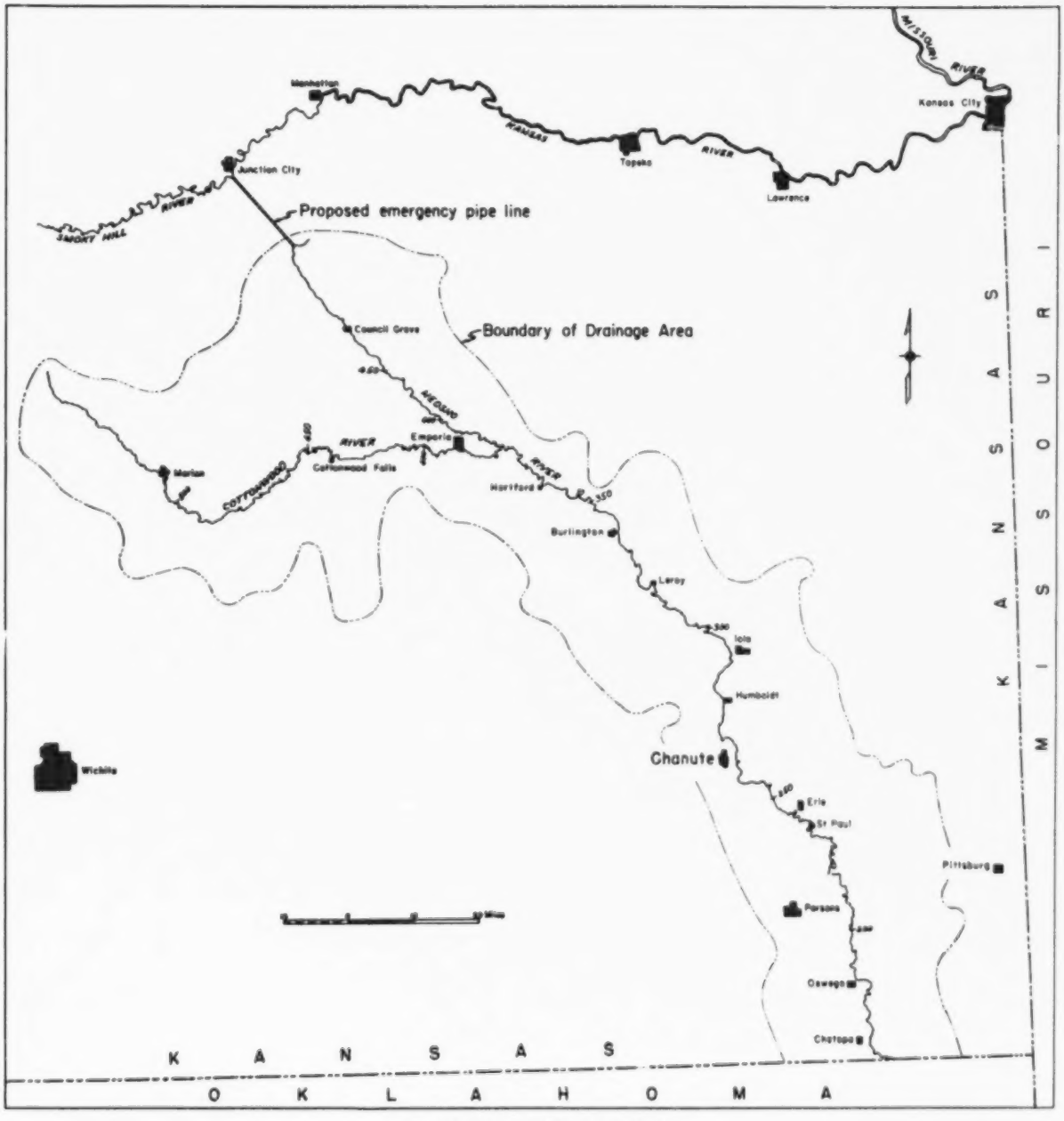
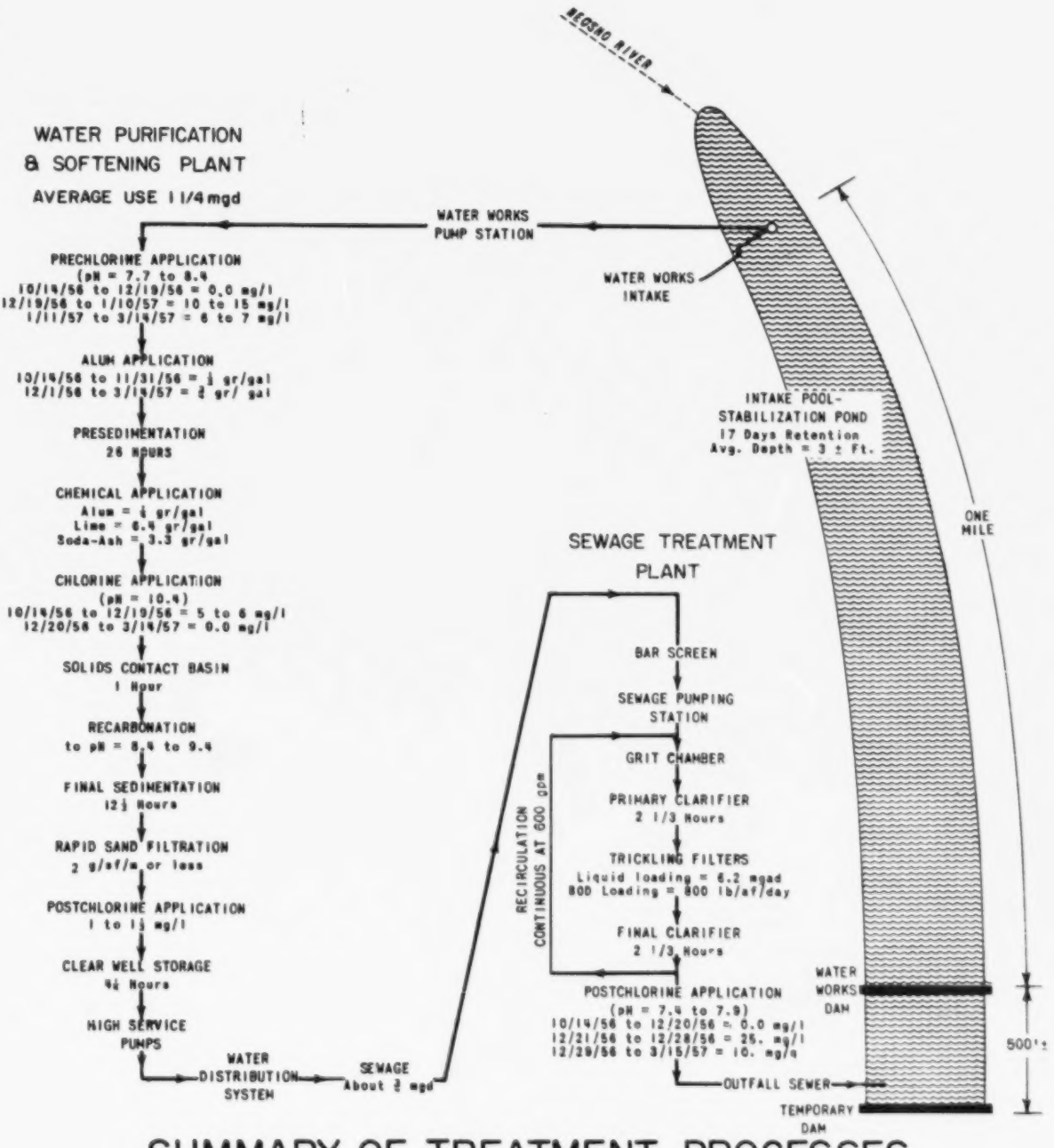


Fig.1 NEOSHO RIVER & VICINITY



SUMMARY OF TREATMENT PROCESSES DURING EMERGENCY REUSE OF WATER AT CHANUTE, KANSAS, 1956-1957

FIGURE 2

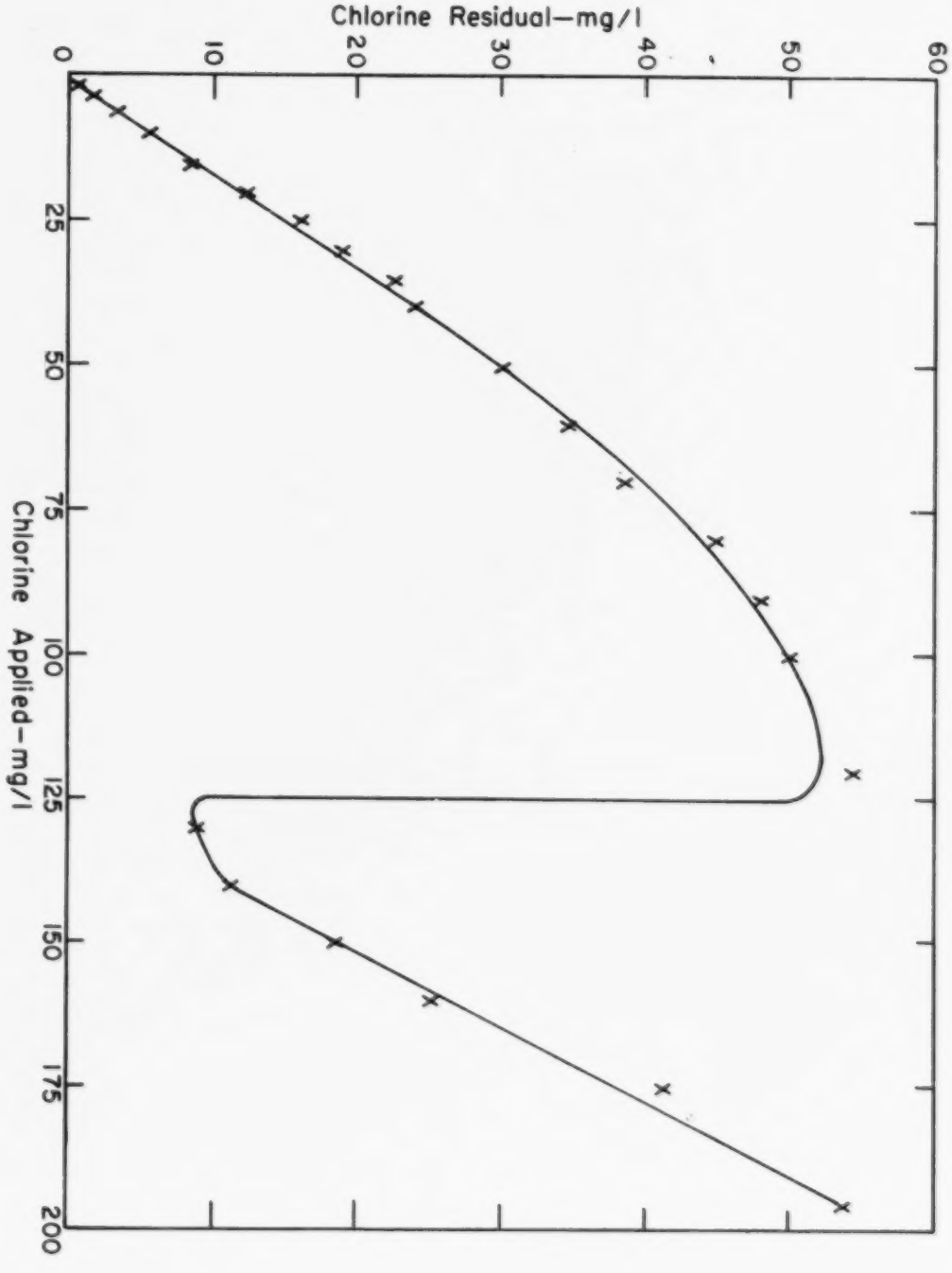


Fig. 3 BREAKPOINT CHLORINATION CURVE
CHANUTE, KANSAS—FEBRUARY 11, 1958

FROTH ON RECARBONATION BASIN, CHANUTE, KANSAS, 1957

FIGURE 4

SUDS IN TAP WATERS FROM CHANUTE AND PARSONS, KANSAS, 1957
PHOTOGRAPH BY PARSONS (KANSAS) SUN

Figure 5

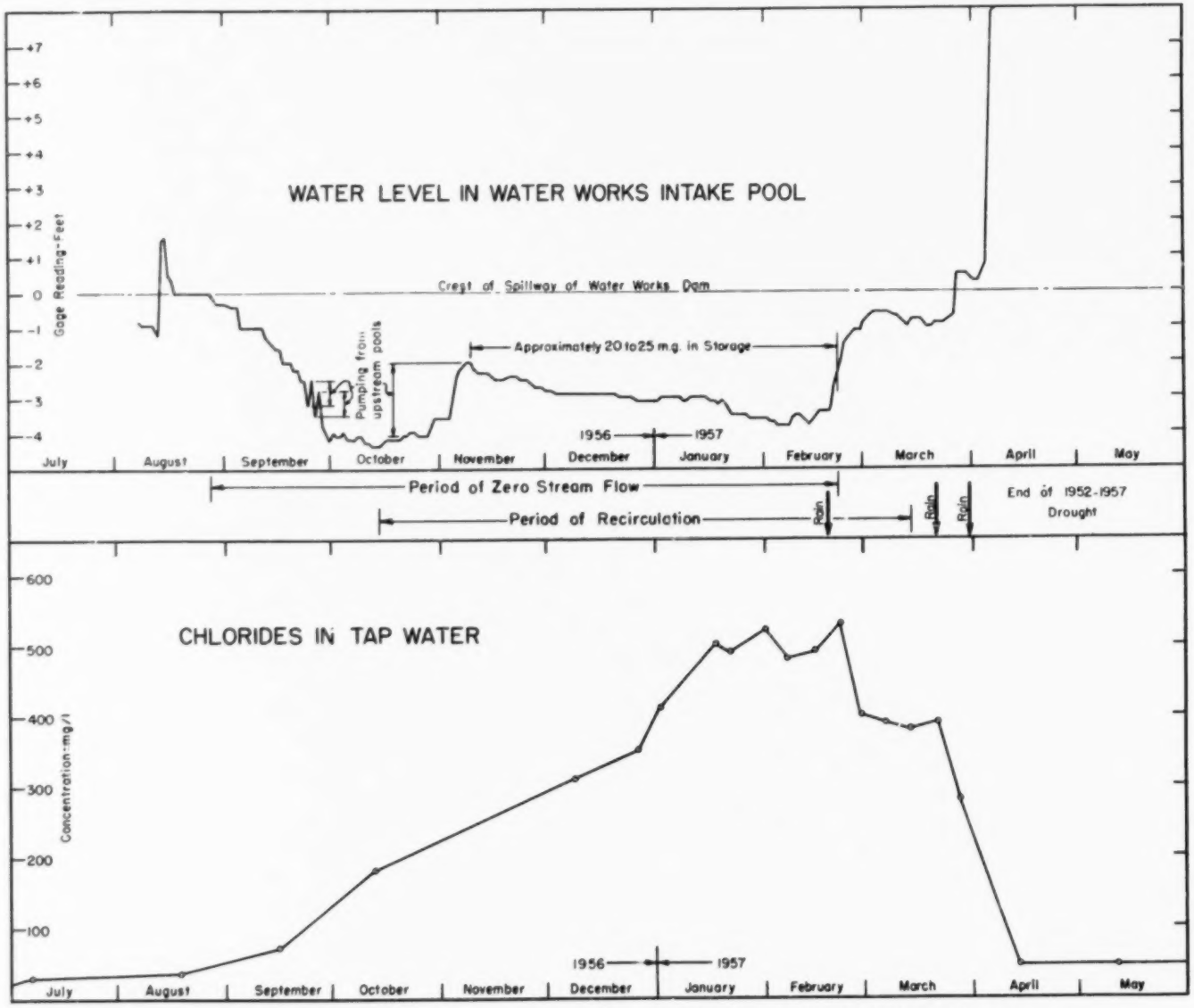


Fig. 6 WATER LEVEL IN WATER WORKS INTAKE POOL AND CHLORIDES IN TAP WATER DURING EMERGENCY REUSE OF WATER, CHANUTE, KANSAS, 1956-1957

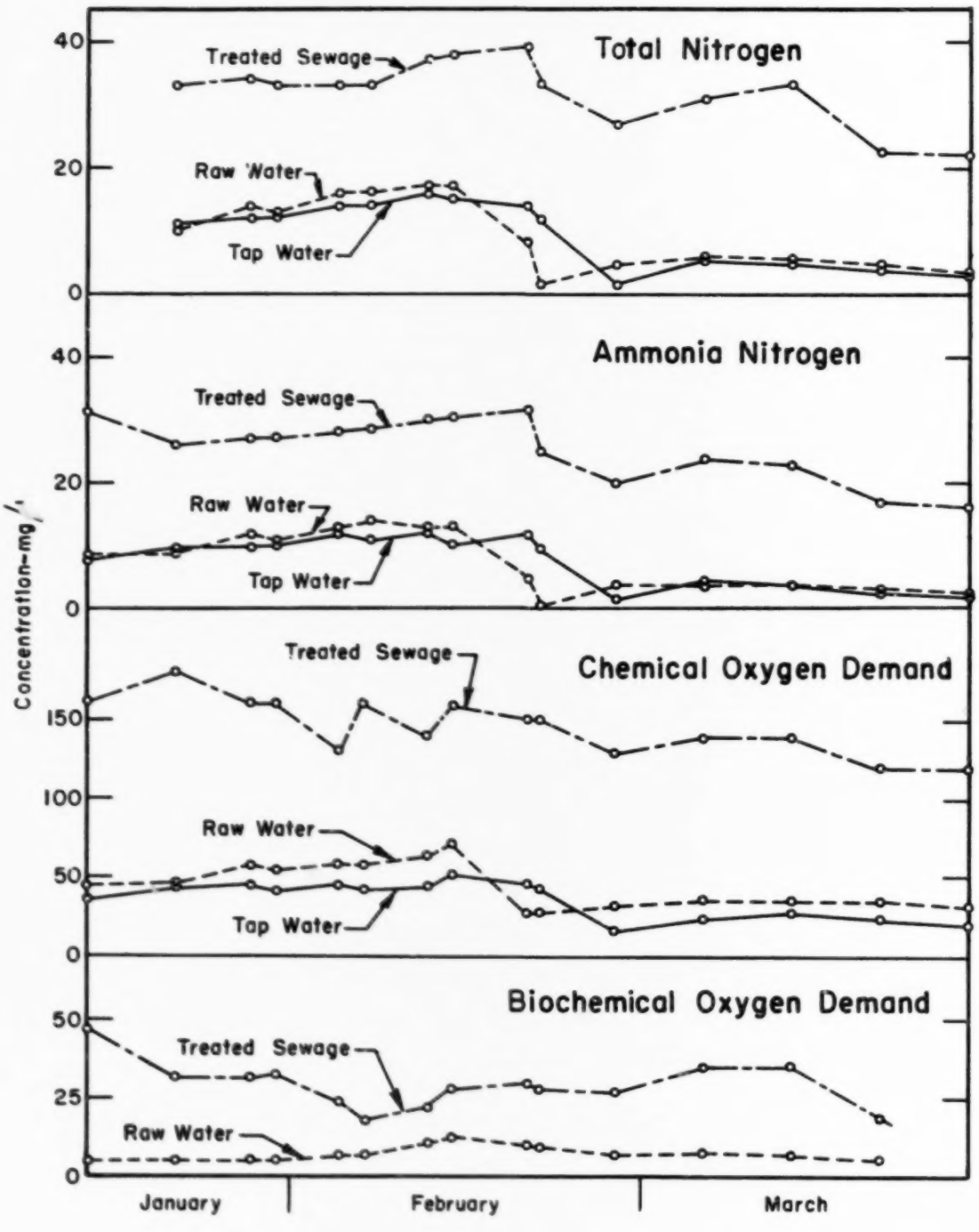


Fig. 7 NITROGEN AND OXYGEN DEMAND CONCENTRATIONS IN TREATED SEWAGE AND RAW AND TAP WATERS CHANUTE, KANSAS, 1957

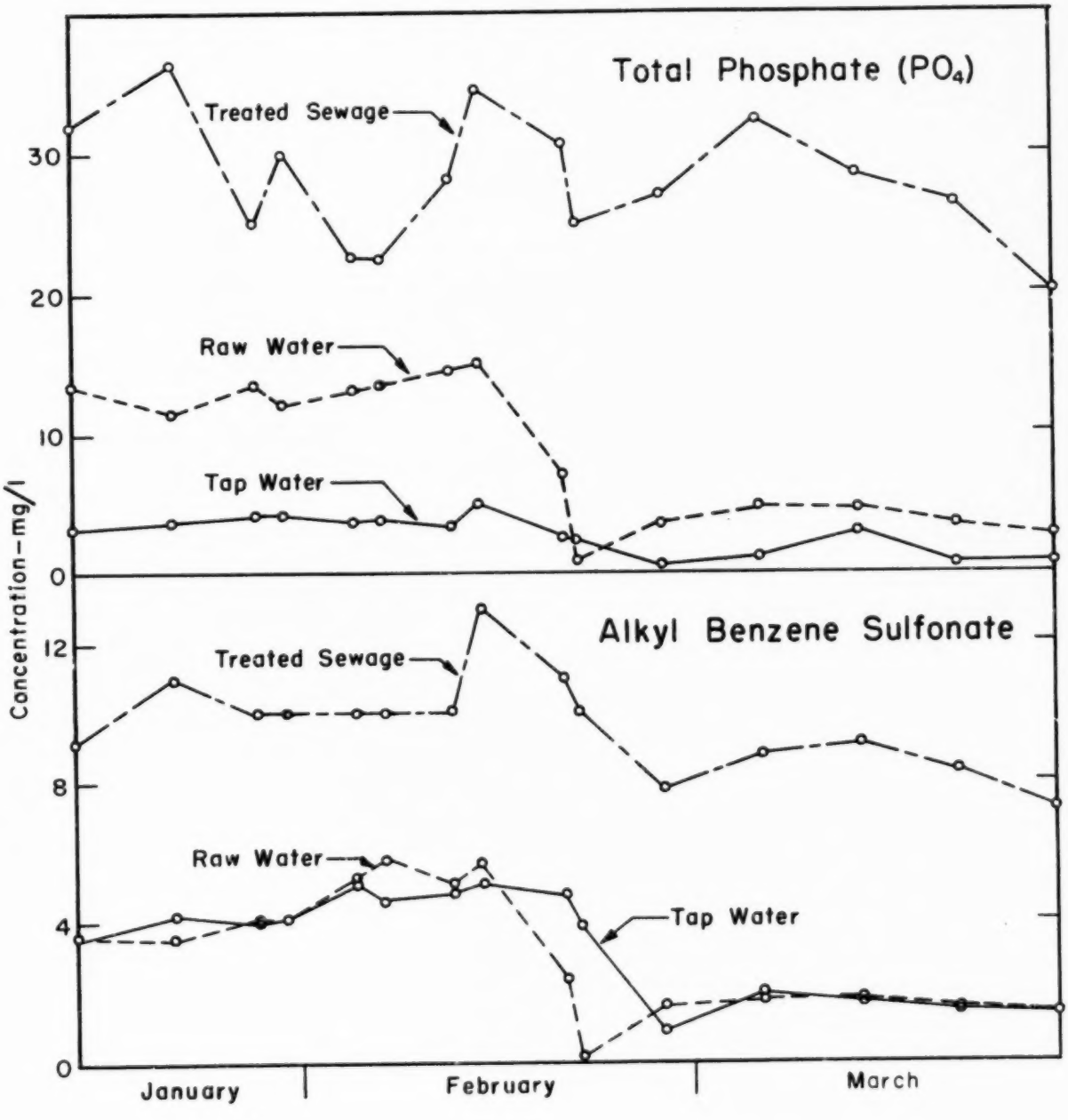


Fig. 8 PHOSPHATE AND ABS CONCENTRATIONS IN TREATED SEWAGE AND RAW AND TAP WATERS CHANUTE, KANSAS, 1957

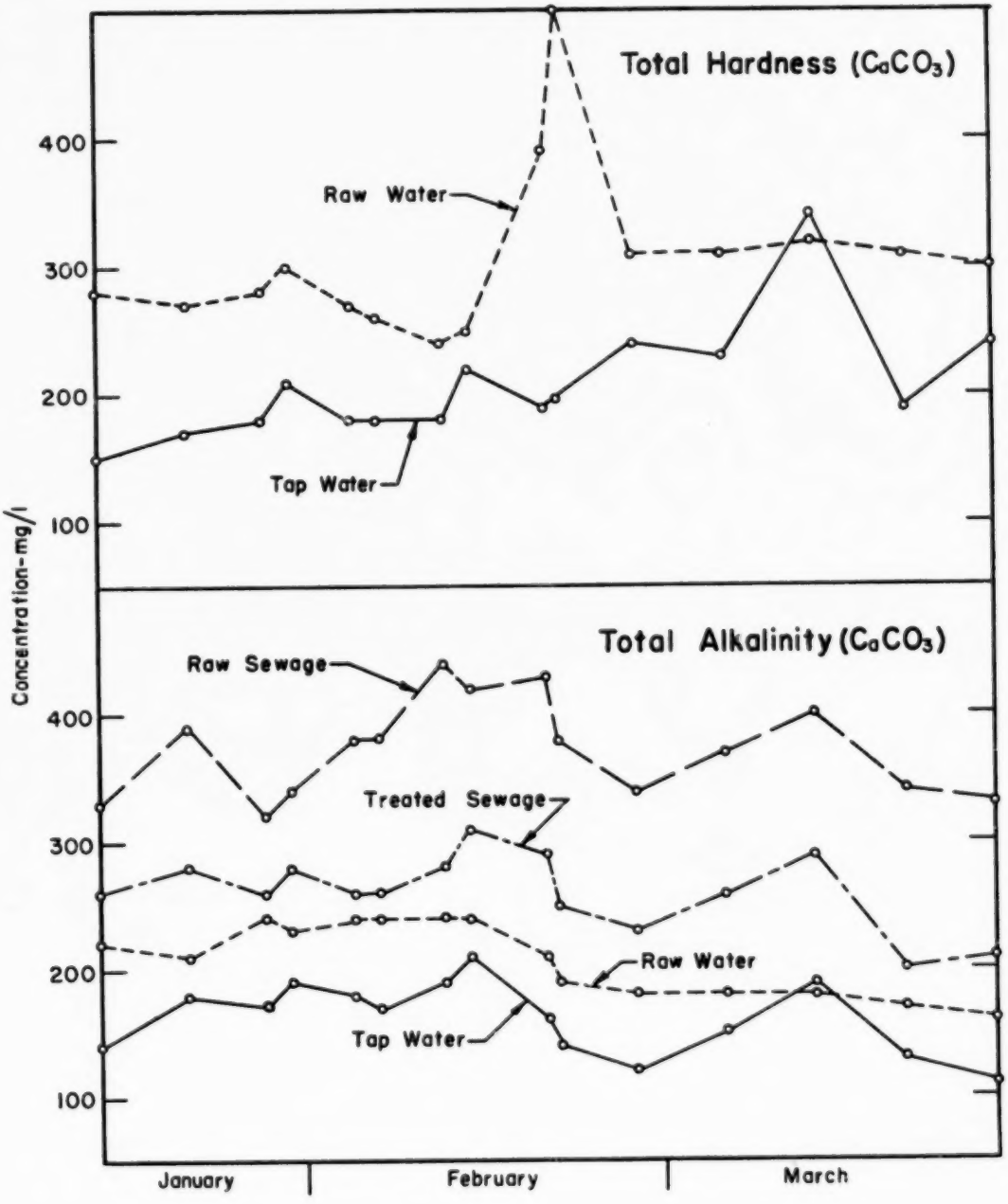


Fig. 9 HARDNESS AND ALKALINITY CONCENTRATIONS IN SEWAGE AND WATER SAMPLES

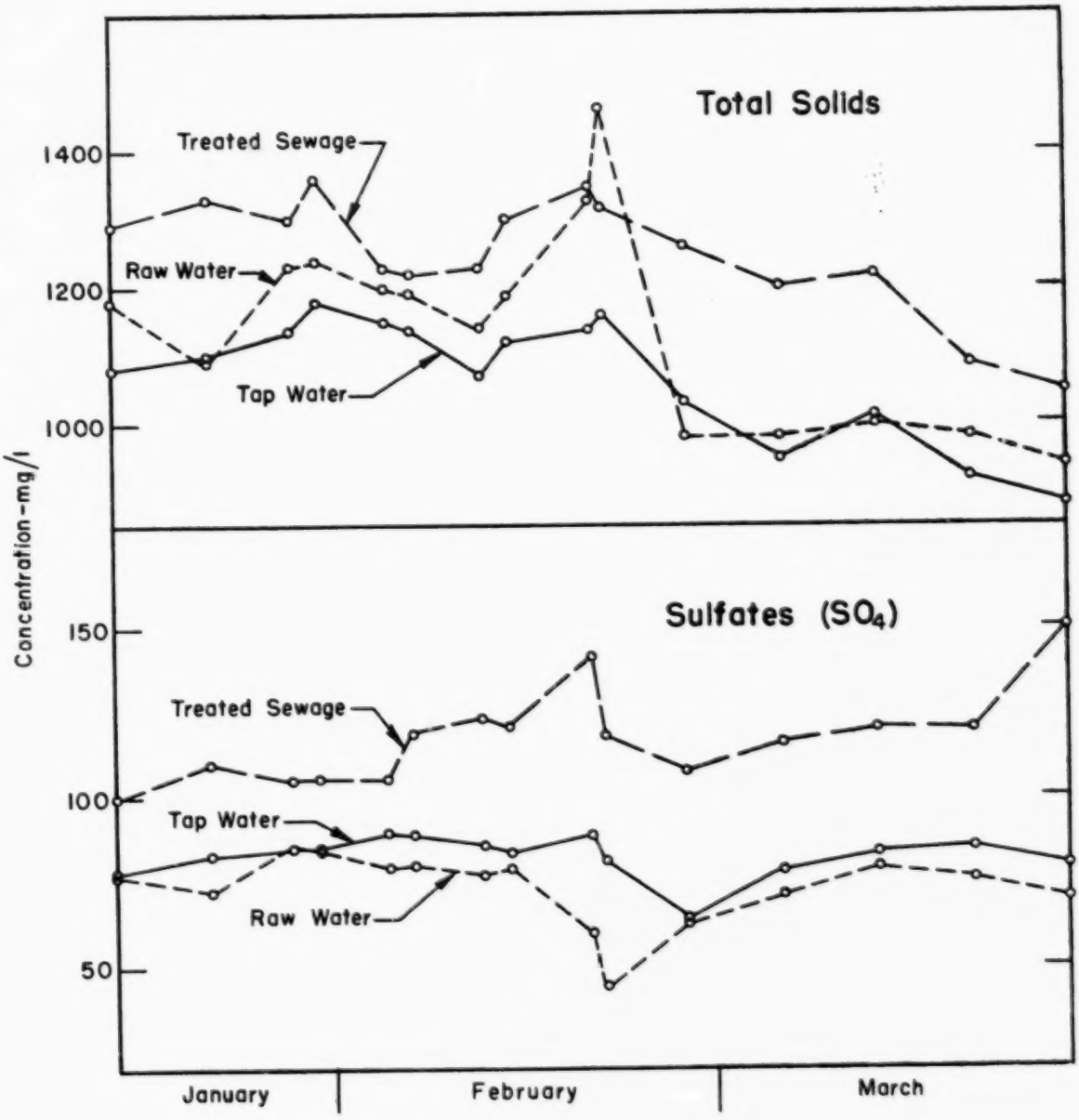


Fig. 10 TOTAL SOLIDS AND SULFATE CONCENTRATIONS IN TREATED SEWAGE AND RAW AND TAP WATERS CHANUTE, KANSAS, 1957

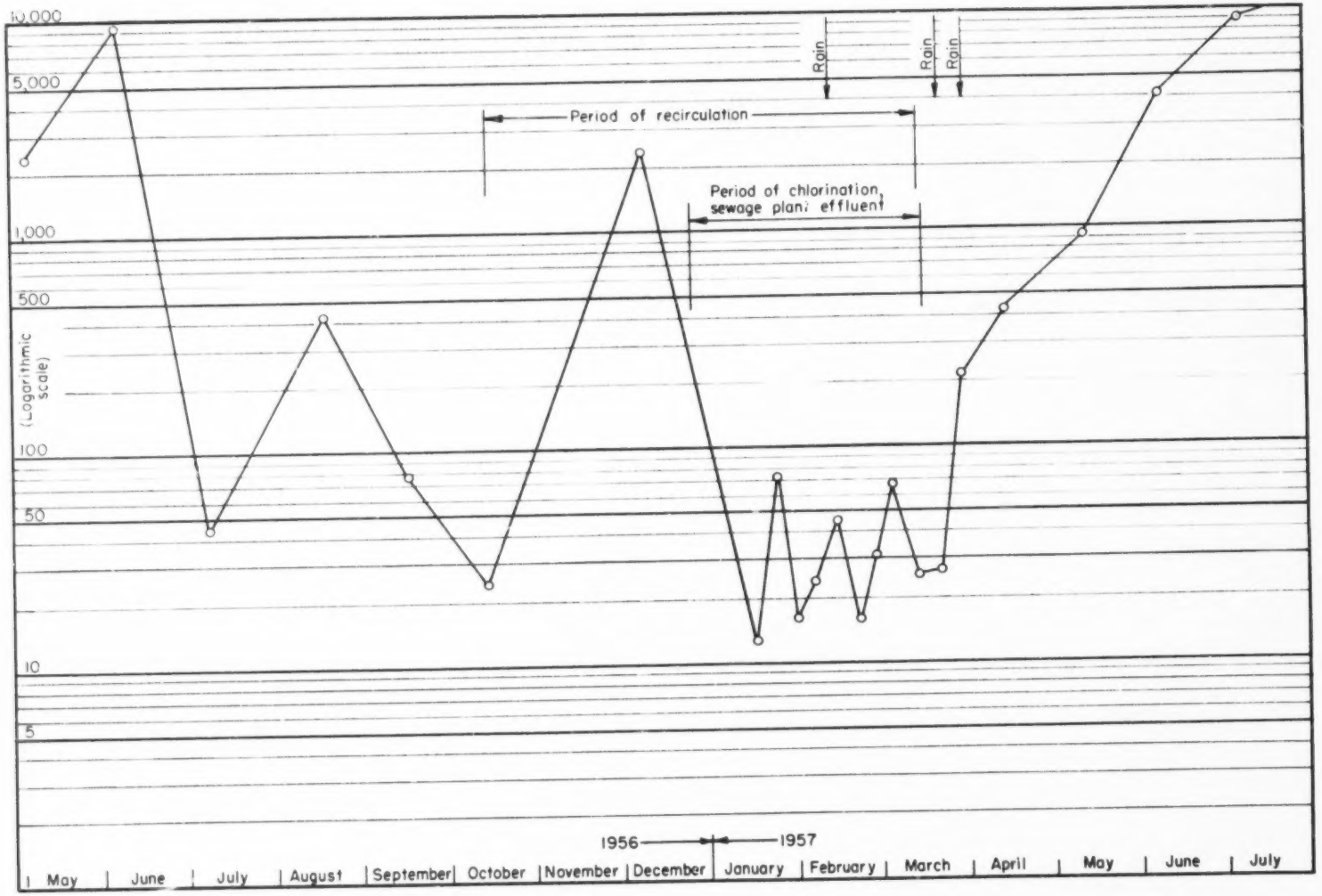


Fig. 11 COLIFORM BACTERIAL DENSITIES IN RAW WATER DURING EMERGENCY REUSE OF WATER CHANUTE, KANSAS 1956–1957

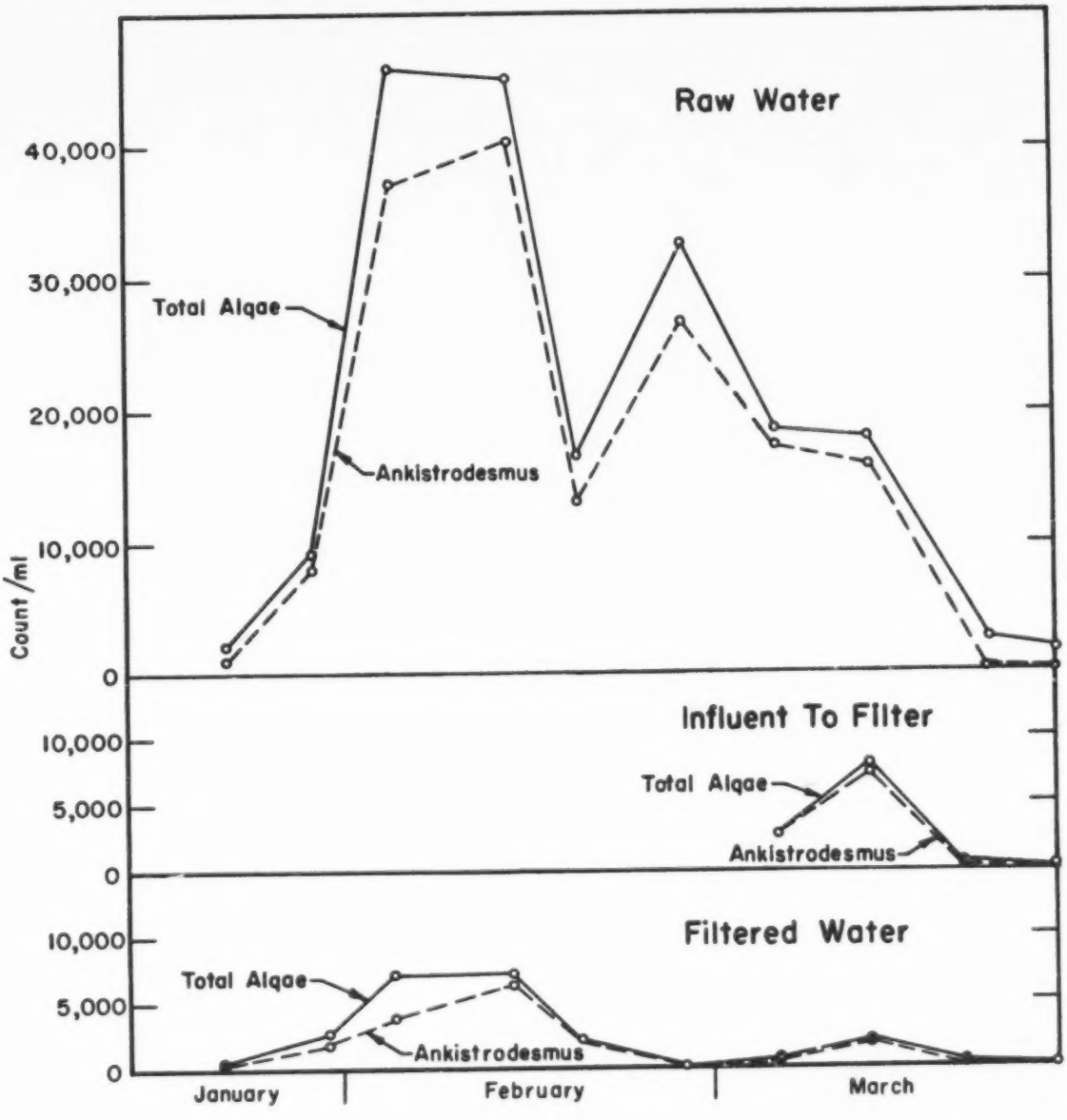


Fig. 12 PLANKTON COUNTS IN RAW, SETTLED AND TAP WATERS DURING EMERGENCY REUSE OF WATER CHANUTE, KANSAS 1957

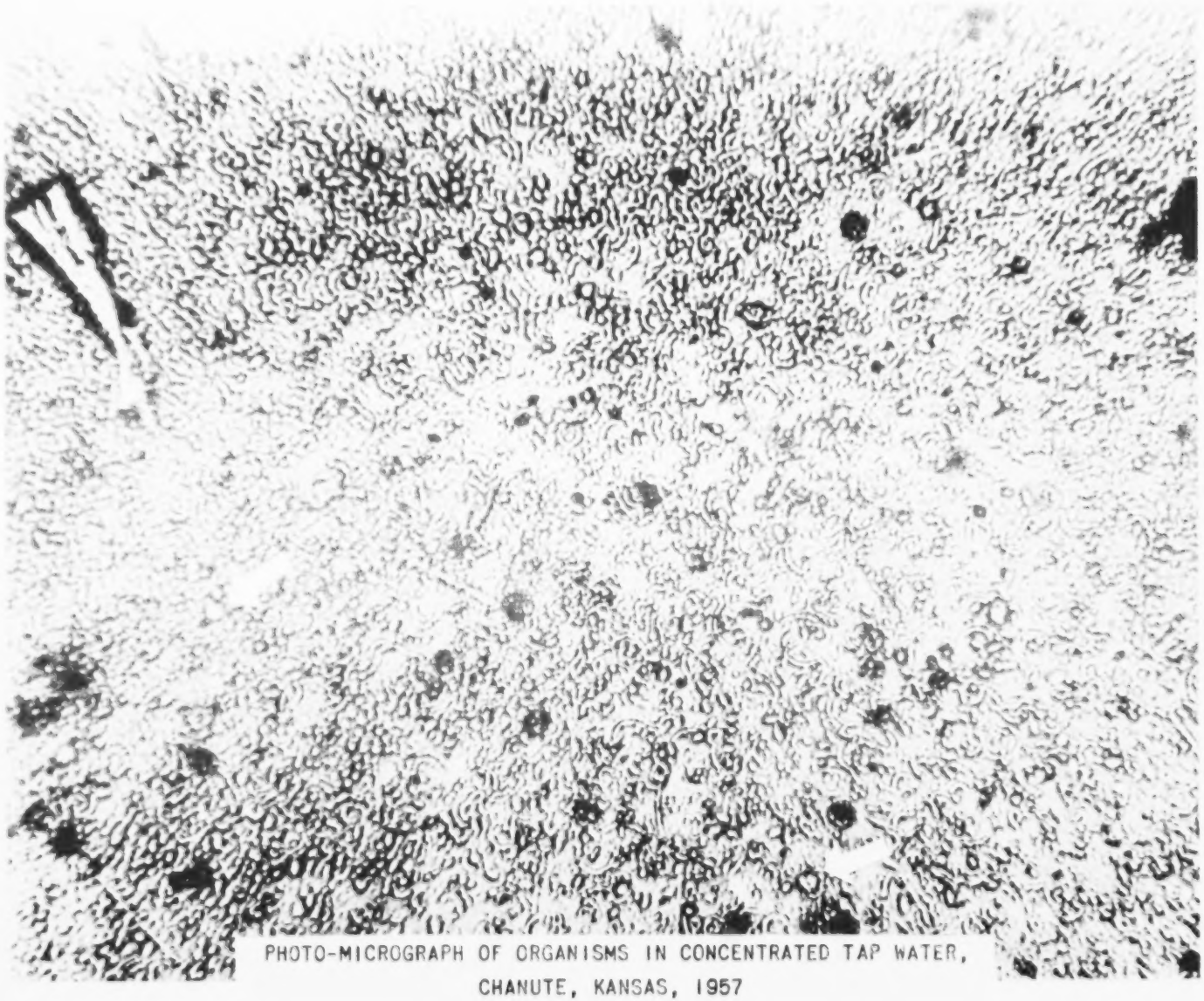


PHOTO-MICROGRAPH OF ORGANISMS IN CONCENTRATED TAP WATER,
CHANUTE, KANSAS, 1957

Figure 13